

SECTION 10.0 HEAVY-DUTY TRUCKS EMISSION FACTORS DEVELOPMENT

10.1 Heavy-Duty Diesel Trucks (HDDT) Emission Factors

Introduction

This section outlines the development of chassis dynamometer test based emission factors for heavy-duty diesel trucks (HDDT). In the MVEI7G model, heavy-duty truck emissions were based on testing various engines on an engine dynamometer rather than testing the entire vehicle on a chassis dynamometer. Basic emission rates were derived from emissions test data collected during HDDT engine certification using the USEPA's heavy-duty engine transient cycle. Emissions from engine testing are expressed as grams per brake horsepower-hour, and must be converted to grams per mile units for use in the emissions inventory models.

The conversion factors used were a function of the fuel density, the brake-specific-fuel consumption (BSFC) of the engine and the fuel economy (miles per gallon) of the vehicle. Because of the wide variation in fuel economy, gross vehicle weight, horsepower ratings, and transmission types, the gram per mile emissions derived from engine dynamometer test data using conversion factors may not be representative of the actual emissions of HDDTs. Further, engine testing is a cost prohibitive method of measuring in-use emissions from vehicles. Unlike light-duty surveillance testing, the testing of HDDTs requires taking a revenue generating truck out of service, pulling the engine, testing and reinstalling it. Emissions estimates based on chassis dynamometer test data are more representative, there is no need for conversion factors and vehicles can be readily tested on the dynamometer. Modeling HDDT emissions based on chassis tests instead of engine tests represents a significant change in EMFAC2000. Therefore, staff organized and consulted several times with members of the "Heavy-Duty Vehicle Emissions Modeling", (HDVEM) advisory committee. Members of this committee represented various HDDT engine manufacturers and its association, university professors with expertise in HDDT chassis testing and emissions modeling, the California Trucking Association and consultants involved either in HDDT chassis testing or emissions modeling.

In EMFAC2000, diesel-powered truckss with a gross vehicle weight of 8,501 pounds or greater are classified in the following manner:

Table 10.1-1 Heavy-Duty Trucks Weight Class

GVW in lbs	Vehicle Class
8,501 to 14,000	Light-Heavy Duty Trucks (LHDT)
14,001 to 33,000	Medium-Heavy Duty Trucks (MHDT)
> 33,000	Heavy-Heavy Duty Trucks (HHDT)

Since 1995, emissions standards for LHDTs have been aligned with medium-duty trucks. Therefore in EMFAC2000, LHDTs are included with medium-duty trucks which are defined as trucks with gross vehicle weight between 8,500 and 14,000 pounds.

10.2 Data Sources

For heavy-heavy and medium-heavy trucks, data from three sources were used to derive the chassis dynamometer based emission rates in EMFAC2000. The first data set, made available by U.S. EPA, was obtained from the New York State Department of Environmental Conservation and Energy (NYSDEC). Under sub-contract to Energy and Environmental Analysis, Inc. (EEA), U.S. EPA and NYSDEC, the West Virginia University (WVU) Department of Mechanical and Aerospace Engineering conducted chassis dynamometer based emissions tests on 35 heavy-heavy and medium-heavy diesel trucks on various chassis test cycles. With the agreement of HDVEM advisory committee, the ARB used emissions test results performed over the EPA Urban Dynamometer Driving Schedule for Heavy-Duty Vehicles (referred to as UDDS or Test-D). The UDDS test cycle (shown in Figure 10.2-A1 of the Appendix) is a chassis dynamometer based test cycle derived from in-use vehicle activity data - the same data used to develop the current heavy-duty engine certification test procedure presented in the Code of Federal Regulations, Title 40, Part 86, Subpart N. It was developed to represent heavy-duty driving in all U.S. Urban areas (40 CFR Part 86 Subpart M). In this study, repeat tests were performed using the UDDS cycle. A substantial decrease in PM emissions was observed between some first and subsequent repeat tests. Staff consulted with WVU personnel who suggested that the differences were due to the fact that sometimes the PM sampling filters were not replaced before the first test. Although WVU personnel agreed to check the database for this discrepancy staff has not received the revised data. In the absence of any other information, staff removed from the analysis, entire emissions test results (HC, CO, NOx, PM and CO₂) of the first test where the difference between the first and second test for PM emissions was greater than 35%.

The second data set was obtained from a report entitled "Heavy-Duty Diesel Vehicle Testing for the Northern Front Range Air Quality Study (NFRAQS)" prepared by the Colorado Institute for Fuels and High Altitude Engine Research (CIFER) at the Colorado School of Mines (CSM). CIFER conducted the study by testing 21 trucks and buses on various test procedures under hot and cold start conditions. Test data from a total of 11 heavy-heavy and medium-heavy diesel trucks tested on the UDDS cycle under hot start conditions were obtained from the database. The tests were conducted at high altitude, therefore, altitude correction factors were applied before emissions test results were merged with other data for this analysis. The altitude correction factors were taken from EPA's report entitled "Update of Heavy-Duty Emission Levels (Model Years 1988-2004+) for Use in MOBILE6", page 23. Table 10.2-1 shows the altitude correction used from the EPA document.

The third data set was obtained from WVU and included tests performed on 4 heavy-heavy diesel trucks on the UDDS cycle. Table 10.2-A1 to A3 in the appendix show the

raw data used to derive the emission rates for heavy-heavy and medium-heavy duty trucks.

Table 10.2-1 Heavy-duty Diesel Vehicle High Altitude Adjustment Factors for HC, CO, NOx, and PM

HC	CO	NOX	PM
2.05	2.46	1.02	1.47

Two data sources were used to derive the emissions rates for light-heavy diesel trucks. The first data set was obtained from the U.S. EPA. The tests were conducted by College of Engineering, Center for Environmental Research and Technology (CE-CERT) in Riverside under contract to the U.S. EPA with the objective to investigate the effect of payload on exhaust emissions. It included bag specific results from 5 trucks tested over the Federal Test Procedure (shown in Figure 10.2-A2 of the Appendix) and three different payloads. Staff used data obtained from testing the trucks at the equivalent test weight (ETW). The ETW is the test weight equal to the empty weight of the vehicle plus 40% fuel fill in the tank. Vehicles in this data set were tested with California reformulated diesel fuel in the tank at the time the vehicle was received. The second data set was obtained from a report entitled "Characterizing Particulate Emissions from Medium- and Light-Heavy Duty Diesel Fueled Vehicles" prepared by CE-CERT for the South Coast Air Quality Management District (SCAQMD). This data set included bag specific FTP test results from 15 trucks tested at the equivalent test weight. Vehicles in this data set were tested with the Federal certification diesel fuel, Type 2-D. Fuel correction factors from Table 10.9-2 were applied to the first data set before they were merged with the second data set.

Table 10.2-A4 in the appendix shows the raw data used to derive emission rates for light-heavy diesel trucks. Table 10.2-A5 in the appendix shows the federal and California standards for heavy-duty trucks. Table 10.1-2 shows the number of trucks from each data set by model year

10.3 Heavy-Heavy Diesel Trucks Emission Rates

The emissions data used in this analysis represented diesel powered heavy-heavy diesel trucks built between 1981 and 1998. In developing the emission factors for EMFAC2000, replicate tests were first averaged for each vehicle. A scatter plot of the resulting emissions as a function of model year, shown in Figures 10.3-1a to 10.3-1d, were then plotted for each pollutant and curve fit to determine the best equation.

Table 10.1-2 Number of Trucks by Weight Class and Model Year

Model Year	HHDT			Total HHDT	MHDT		Total MHDT	LHDT		Total LHDT
	NYSDEC	CIFER	WVU		NYSDEC	CIFER		SCAQMD-CE-CERT	EPA-CE-CERT	
1966	1	---	---	1	---	---	---	---	---	---
1981	---	1	---	1	---	---	---	---	---	---
1982	---	---	1	1	---	---	---	1	---	1
1983	---	1	---	1	---	---	---	---	---	---
1984	1	---	---	1	---	---	---	1	---	1
1985	1	---	1	2	1	---	1	2	---	2
1986	---	---	---	---	---	---	---	1	---	1
1987	---	---	---	---	1	1	2	2	---	2
1988	2	---	---	2	1	---	1	---	1	1
1989	1	---	---	1	1	2	3	1	---	1
1990	---	1	---	1	2	1	3	---	---	---
1991	1	---	---	1	---	---	---	---	1	1
1992	---	---	---	---	2	---	2	1	---	1
1993	1	1	---	2	2	2	4	---	1	1
1994	1	---	---	1	2	---	2	3	1	4
1995	---	1	1	2	2	---	2	1	1	2
1996	1	---	---	1	4	---	4	2	---	2
1997	1	---	---	1	1	---	1	---	---	---
1998	3	---	1	4	1	---	1	---	---	---
1999	---	---	---	---	1	---	1	---	---	---
Total	14	5	4	23	21	6	27	15	5	20

Regression equations were used to calculate the average emission rates for model years that were within the data points, i.e. model years 1981 to 1998. Model years prior to 1981 were assumed to have the same average emission rate as the 1981 model year. For model years 1999 and later, an average emission rate was calculated by multiplying the average emission rate of the 1991-93 model year group by the ratio of the standards of the 1999+ model year to the 1991-93 model year groups. The 1991-93 model year group was considered as a basis for calculating the 1999+ model year average emissions because this group had the lowest NOx emissions and therefore was considered to be free of off-cycle NOx. For CO2 emissions an average of all model year emissions was calculated and applied to all model year groups. The resulting average emission rates by technology groups are shown in Table 10.3-1.

The scatter plot for NOx emissions, Figure 10.3-1, shows an increase in emissions between model years 1993 and 1998 although the NOx standard decreases from 5 g/bhp-hr in 1993 to 4 g/bhp-hr in 1998. A possible explanation is “off-cycle NOx”. Off-cycle NOx emissions are excess emissions produced by heavy-duty diesel engines as a result of defeat devices programmed to default to a fuel economy mode during periods of sustained cruise. This mode of operation is outside of the limits of the engine certification test and therefore, the excess emissions are not captured during certification

testing. The majority of heavy-duty diesel engines produced between 1988 to 1998 display off-cycle NOx emissions. In EMFAC2000, it is assumed that off-cycle NOx would be eliminated by the 1999 model year. As a part of the settlement, an agreement (Consent Decree) was reached between the EPA and heavy-duty diesel engine manufacturers involved with defeat devices to meet a 2 g/bhp-hr NOx emissions standard originally scheduled for 2004, in October of 2002. Based on projected engine production estimates submitted by engine manufacturers during certification, for calendar year 1998, the market share of heavy-heavy diesel engines manufactures involved in the consent decree was 99.9% of the total market of heavy-heavy diesel engines. Therefore, in EMFAC2000, it is assumed that 99.9% of the 2003 model year heavy-duty engines will be subject to the 2 g/bhp-hr NOx emissions standard and the remaining 0.1% will meet a 4 g/bhp-hr. In 2004, 100% of the heavy-duty engines will meet the 2 g/bhp-hr NOx emissions standard.

For CO₂ emissions, the scatter plot of the data points did not produce a well correlated regression equation. Therefore, an average of all model year emissions was calculated and applied for all model years.

10.4 Medium-Heavy Diesel Truck Emission Rates

The same procedure used for heavy-heavy duty trucks was followed in calculating the average emission rates of medium-heavy diesel trucks. First, averages of replicate tests were calculated for each truck and the resulting emissions were then plotted as a function of the model years (Figures 10.4-1a to 10.4-1d). For each pollutant, a regression equation was obtained by passing a best fit curve through the data points. Using the equations, average emission rates were calculated for each model year within the data points (1985 to 1999). Model years prior to 1985 were assumed to have the same average emission rates as the 1985 model year. For model years 2000 and later, average emission rates were calculated by taking the ratio of standards with respect to the 1998-99 model year and multiplying by the 1998-99 model year group average emission rate.

Based on projected engine production estimates submitted by engine manufacturers during certification, for calendar year 1998, the market share of medium-heavy diesel engines manufactures involved in the consent decree was 94.1% of the total market of medium-heavy diesel engines. Therefore, in EMFAC2000, it is assumed that 94.1% of the 2003 model year medium-heavy diesel engines will be subject to the 2 g/bhp-hr NOx emissions standard and the remaining 5.9% will meet a 4 g/bhp-hr standard. In 2004, 100% of the heavy-duty engines will meet the 2 g/bhp-hr NOx emissions standard. Tables 10.4-1 show the average emission rates for each technology group of medium-heavy diesel trucks.

CO₂ emissions were calculated in a similar way as in heavy-heavy duty engines.

10.5 Light-Heavy Diesel Truck Emission Rates

A scatter plot of the emissions results by model year for each pollutant showed two distinct groups of data points. The first group, corresponding to model years prior to 1990, had lower NOx and higher PM emissions while the second group, corresponding to model years 1991 and later had higher NOx and lower PM emissions. This change in emissions is the transition from indirect to direct injection technology. For each pollutant, two average emission rates were calculated, one for model years before 1990 and a second for model years after 1990. These averages were applied for model years that are within the data set, i.e. 1982 to 1996. Model years prior to 1982 were assumed to have the same average emission rate as the 1982 model year. For model years after 1996, the average emission rates were calculated using the ratio of standards and the average emission rate of the 1991-93 model year group. Table 10.5-1 and Table 10.5-2 show the average emission rates and figure 10.5-1a to 10.5-1h show a plot of the average emission rates.

10.6 Federal Heavy-Heavy Diesel Truck Emission Rates

The same procedure used for California certified heavy-heavy diesel trucks was followed to calculate the average emission rates for federally certified heavy-heavy diesel trucks. Except for the difference in the technology groups, the two methods are identical. The calculated average emission rates are shown in Table 10.6-1.

Figure 10.3-1a HHDT NOx Emissions

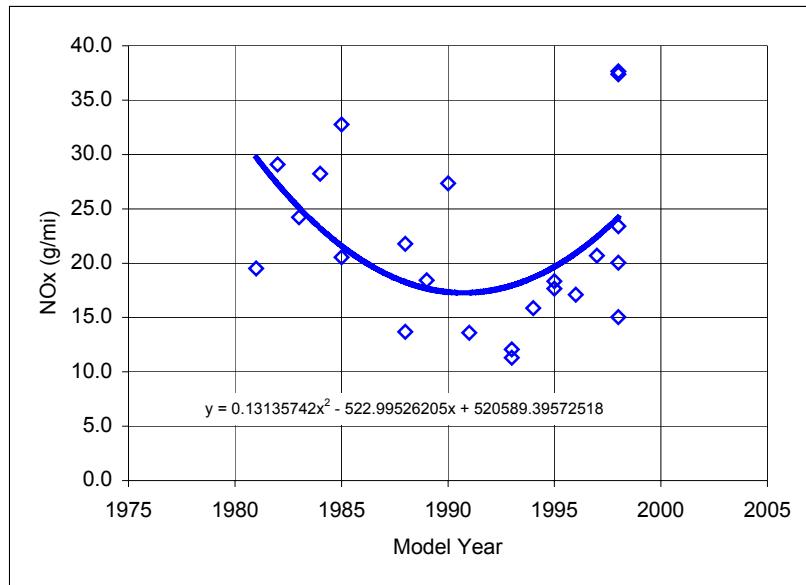


Figure 10.3-1b HHDT PM Emissions

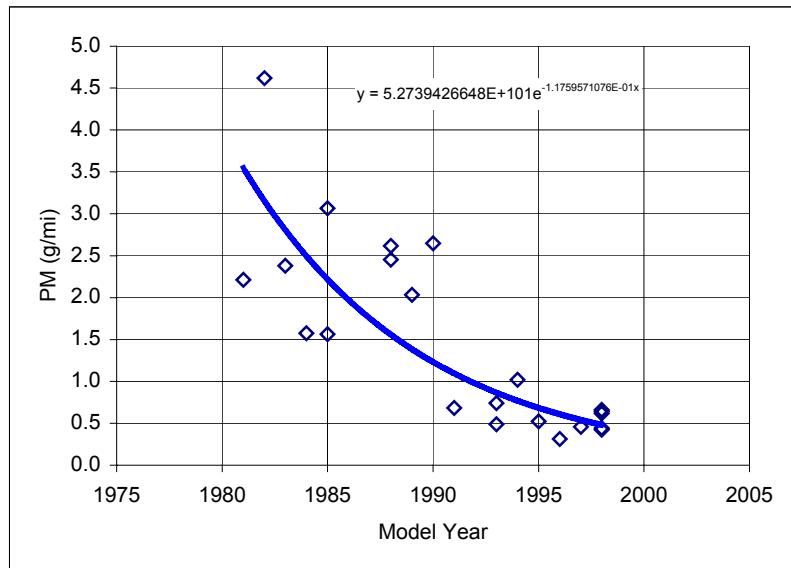


Figure 10.3-1c HHDT HC Emissions

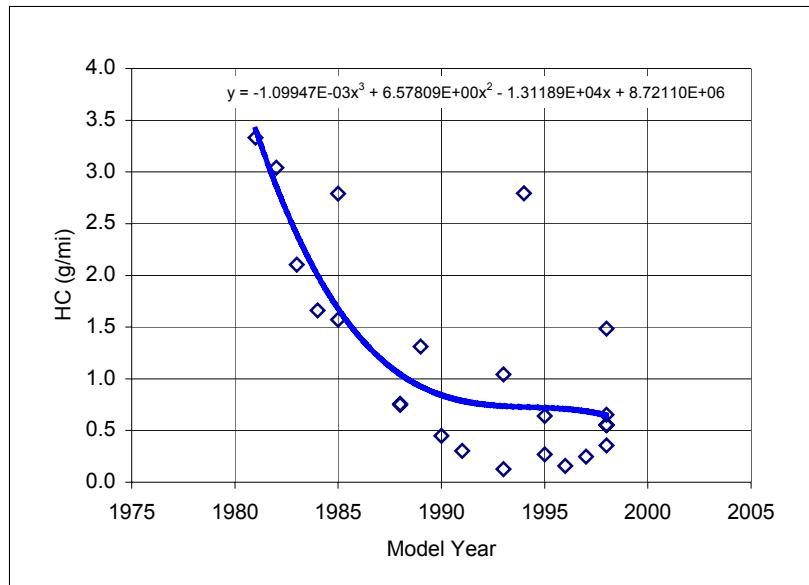


Figure 10.3-1d HHDT CO Emissions

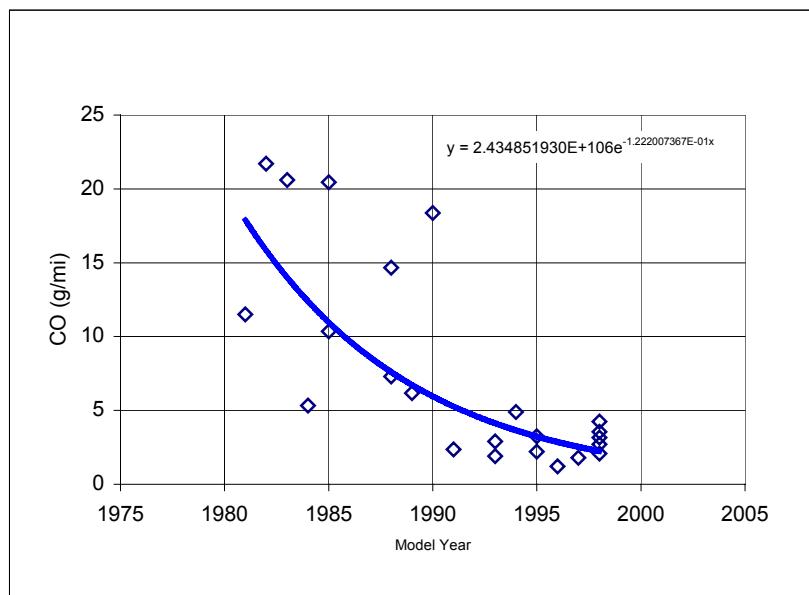


Table 10.3-1 Heavy-Heavy Diesel - Average Emission Rates (g/mi)

California – Heavy-Heavy Diesel Trucks					
MY Group	HC	CO	NOX	PM	CO ₂
Pre 1975	3.41	17.89	29.72	3.55	2179
1975-76	3.10	16.70	28.32	3.32	2179
1977-79	3.10	16.70	28.32	3.32	2179
1980-83	3.10	16.70	28.32	3.32	2179
1984-86	1.57	10.42	21.04	2.11	2179
1987-90	0.94	6.76	17.76	1.39	2179
1991-93	0.76	4.69	17.57	0.98	2179
1994-97	0.71	3.07	20.42	0.65	2179
1998	0.65	2.24	24.21	0.48	2179
1999-02	0.65	2.24	14.06	0.39	2179
2003	0.32	2.24	7.03	0.39	2179
2004	0.32	2.24	7.03	0.39	2179

Figure 10.4-1a Medium-Heavy Diesel NOx Emissions

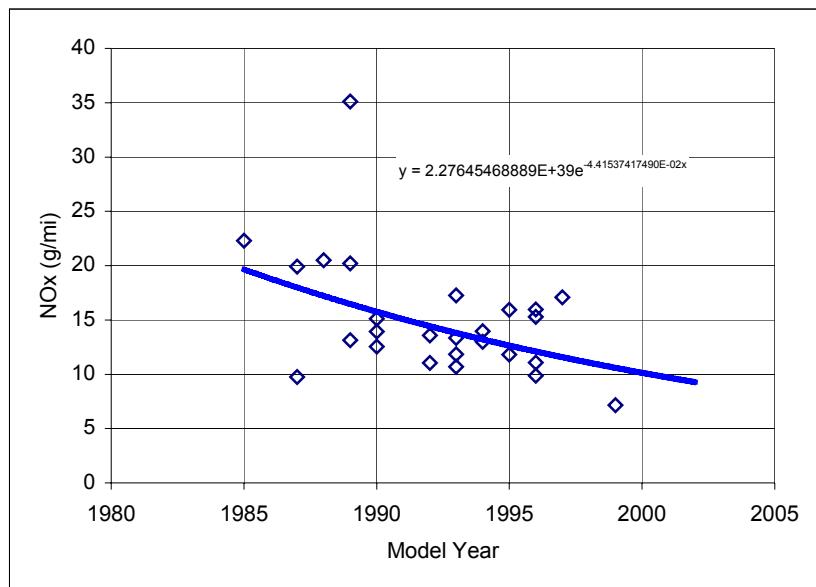


Figure 10.4-1b Medium-Heavy Diesel PM Emissions

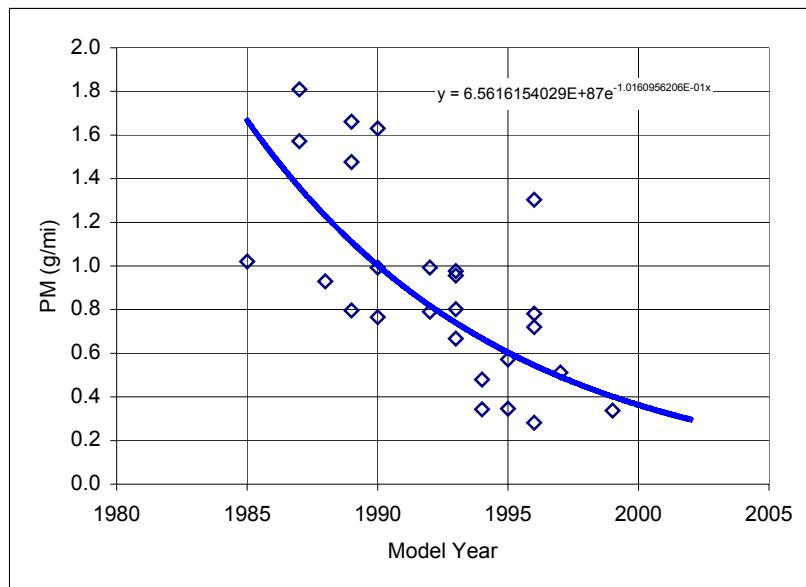


Figure 10.4-1c Medium-Heavy Diesel HC Emissions

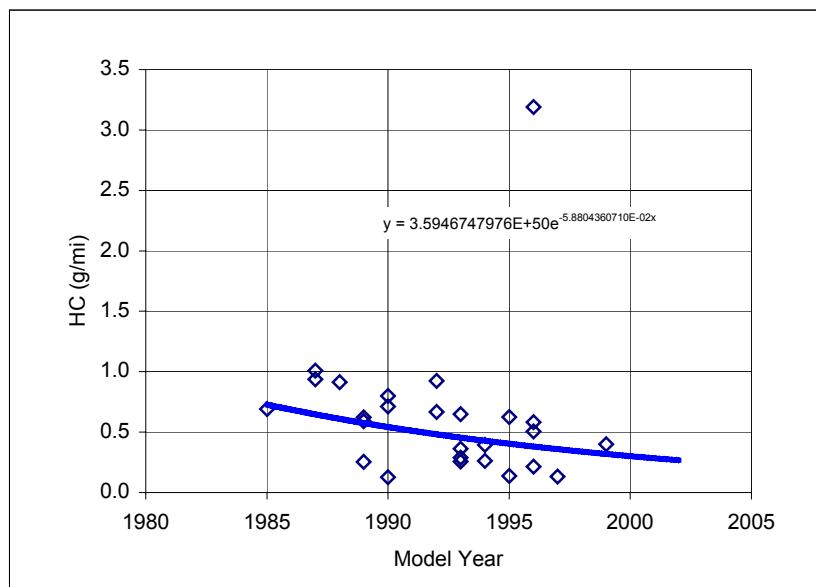


Figure 10.4-1d Medium-Heavy Diesel CO Emissions

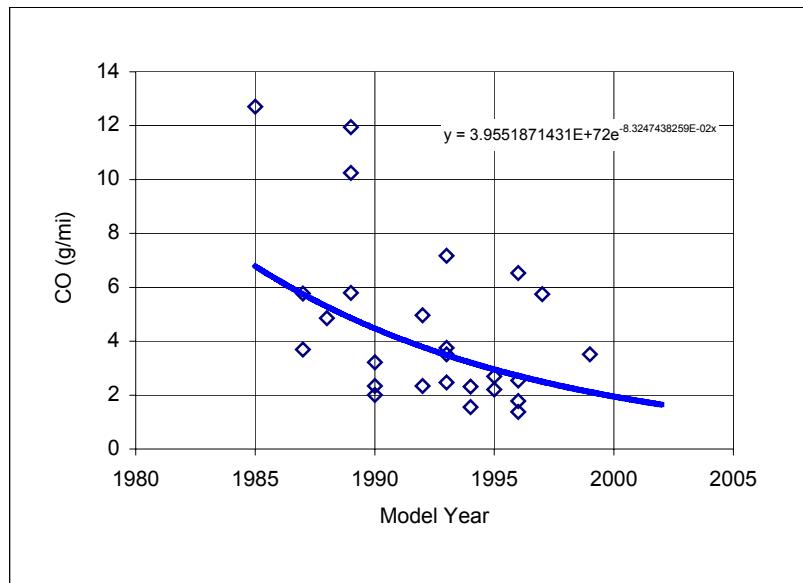


Table 10.4-1 Medium-Heavy Diesel - Average Emission Rates (g/mi)

California – Medium-Heavy Diesel Trucks					
MY Group	HC	CO	NOX	PM	CO ₂
Pre 1975	0.73	6.79	19.65	1.67	1505
1975-76	0.73	6.79	19.65	1.67	1505
1977-79	0.73	6.79	19.65	1.67	1505
1980-83	0.73	6.79	19.65	1.67	1505
1984-86	0.70	6.39	19.03	1.55	1505
1987-90	0.58	4.88	16.48	1.11	1505
1991-93	0.48	3.80	14.44	0.82	1505
1994-97	0.39	2.84	12.38	0.58	1505
1998	0.34	2.30	11.07	0.44	1505
1999-02	0.34	2.30	11.07	0.44	1505
2003	0.21	2.30	6.09	0.44	1505
2004+	0.20	2.30	5.78	0.44	1505

Figure 10.5-1a Light-Heavy Diesel - BAG1 NOx Emissions

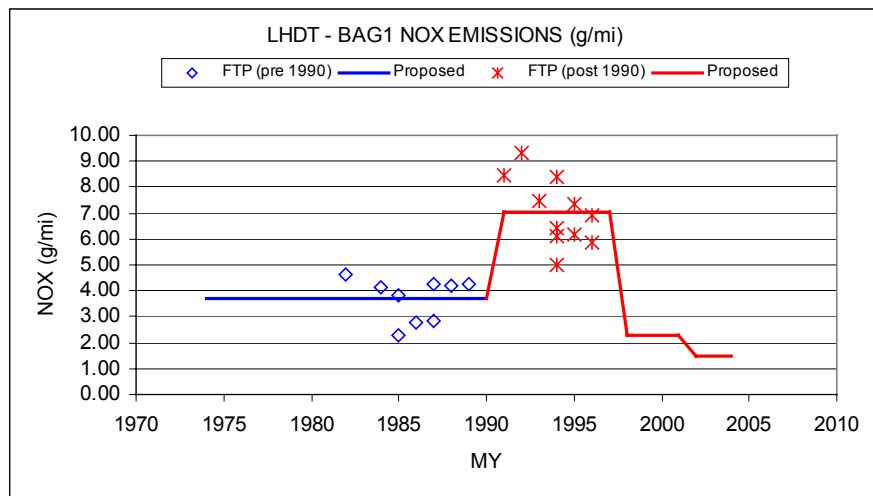


Figure 10.5-1b Light-Heavy Diesel – BAG1 PM Emissions

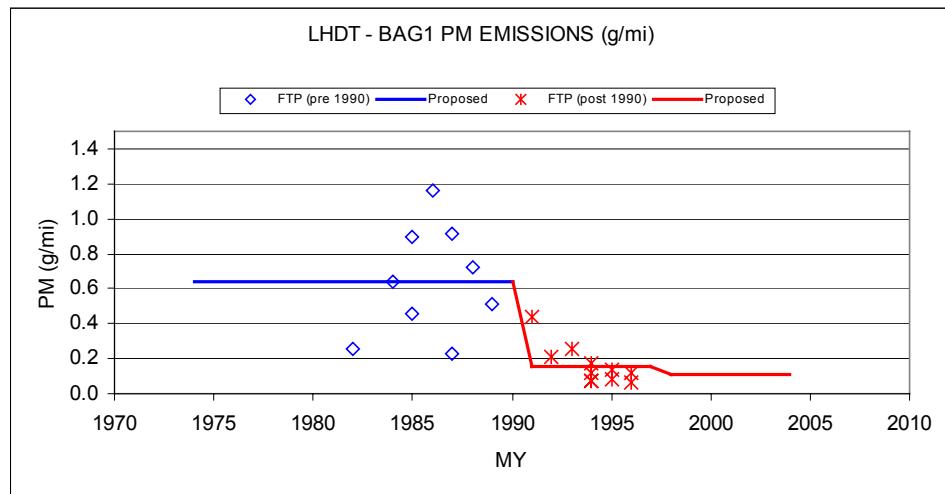


Figure 10.5-1c Light-Heavy Diesel - BAG1 HC Emissions

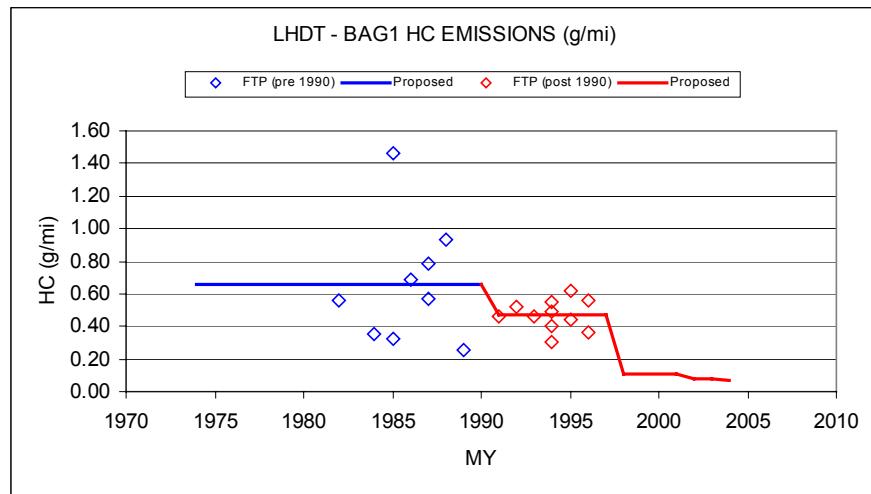


Figure 10.5-1d Light-Heavy Diesel - BAG1 CO Emissions

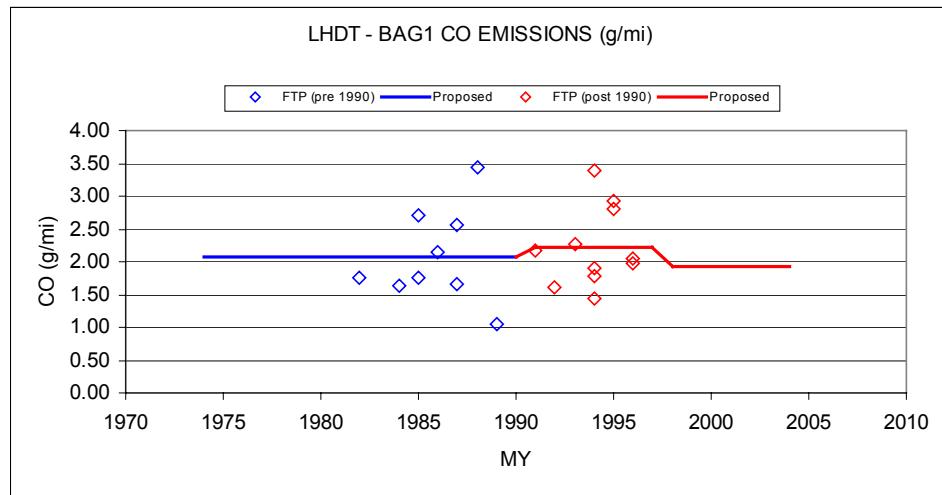


Figure 10.5-1e Light-Heavy Diesel – BAG2 NOX Emissions

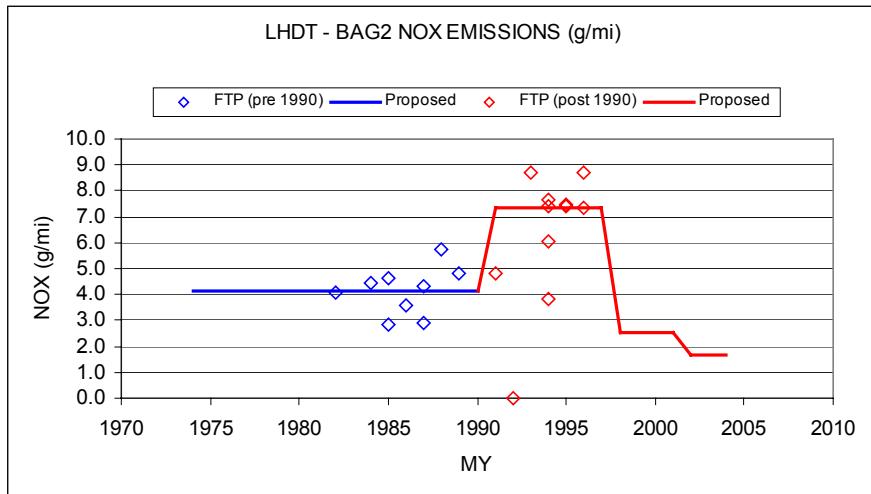


Figure 10.5-1f Light-Heavy Diesel – BAG2 PM Emissions

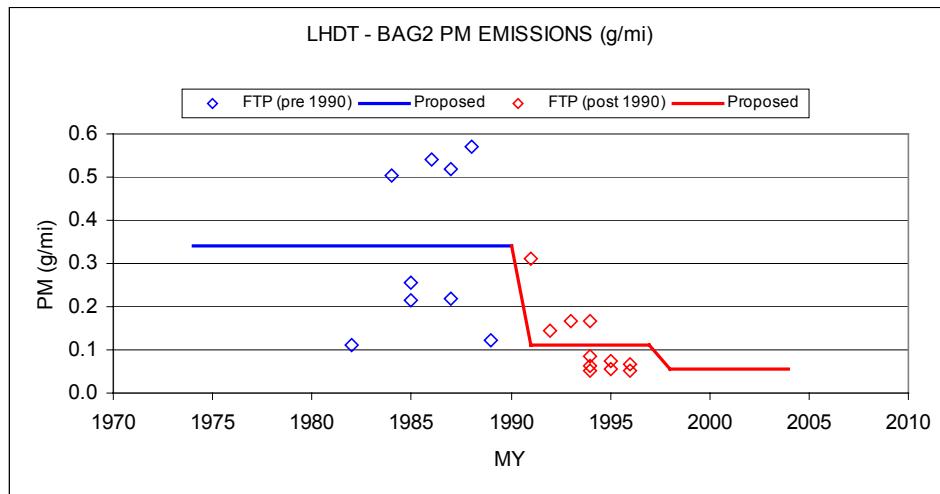


Figure 10.5-1g Light-Heavy Diesel – BAG2 HC Emissions

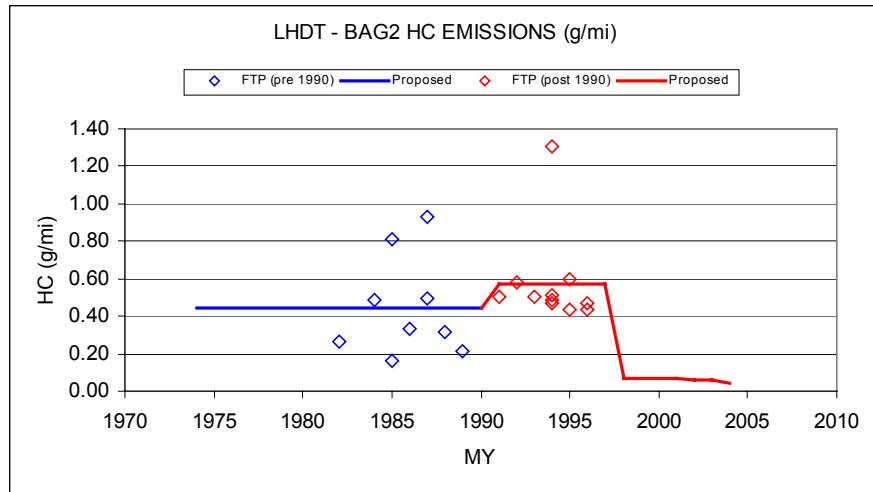


Figure 10.5-1h Light-Heavy Diesel – BAG2 CO Emissions

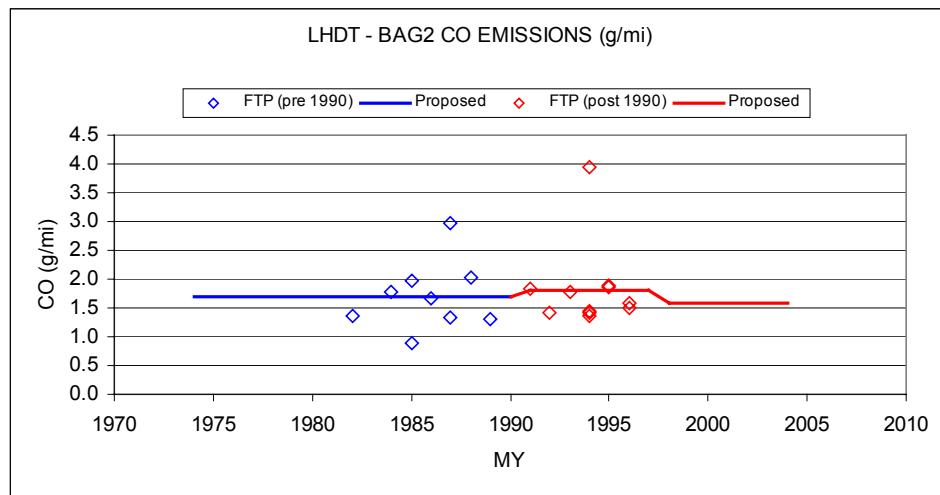


Table 10.5-1 Light-Heavy Diesel - Average Emission Rates (g/mi)

California – Light-Heavy Diesel Trucks										
MY Group	BAG1					BAG2				
	THC	CO	NOX	PM	CO2	THC	CO	NOX	PM	CO2
Pre 1975	0.66	2.08	3.86	0.77	745	0.45	1.70	4.32	0.40	642
1975-76	0.66	2.08	3.86	0.77	745	0.45	1.70	4.32	0.40	642
1977-79	0.66	2.08	3.86	0.77	745	0.45	1.70	4.32	0.40	642
1980-83	0.66	2.08	3.86	0.77	745	0.45	1.70	4.32	0.40	642
1984-86	0.66	2.08	3.86	0.77	745	0.45	1.70	4.32	0.40	642
1987-90	0.66	2.08	3.86	0.77	745	0.45	1.70	4.32	0.40	642
1991-93	0.47	2.21	7.28	0.15	678	0.57	1.82	7.64	0.11	601
1994	0.47	2.21	7.28	0.15	577	0.57	1.82	7.64	0.11	540
1995	0.47	2.21	7.28	0.15	544	0.57	1.82	7.64	0.11	519
1996-97	0.47	2.21	7.28	0.15	544	0.57	1.82	7.64	0.11	519
1998-99	0.11	1.93	2.38	0.13	544	0.07	1.58	2.67	0.07	519
2000-01	0.11	1.93	2.38	0.13	544	0.07	1.58	2.67	0.07	519
2002-03	0.08	1.93	1.53	0.13	544	0.06	1.58	1.71	0.07	519
2004+	0.07	1.93	1.53	0.13	544	0.05	1.58	1.71	0.07	519

Table 10.6-1 Federal Heavy-Heavy Diesel - Average Emission Rates (g/mi)

Federal – Heavy-Heavy Diesel Trucks					
MY Group	HC	CO	NOX	PM	CO ₂
pre 1974	3.41	17.89	29.72	3.55	2179
1974-78	3.41	17.89	29.72	3.55	2179
1979-83	3.10	16.70	28.32	3.32	2179
1984-87	1.57	10.42	21.04	2.11	2179
1988-90	0.94	6.76	17.76	1.39	2179
1991-93	0.76	4.69	17.57	0.98	2179
1994-97	0.71	3.07	20.42	0.65	2179
1998	0.65	2.24	24.21	0.48	2179
1999-02	0.65	2.24	14.06	0.39	2179
2003	0.32	2.24	7.03	0.39	2179
2004+	0.32	2.24	7.03	0.39	2179

10.7 Effect of Tampering and Malfunctions on Heavy-Duty Diesel Truck Emissions

- Deterioration Rates

It is assumed that the emissions from diesel powered trucks will remain stable in the absence of tampering, malfunction and malmaintenance. The deterioration factors to be used in EMFAC2000 are based upon the assumption of the frequency of occurrence and consequence of nineteen specific instances of tampering and malmaintenance which are the same as those used in MVEI7G and outlined in the Radian Corporation (Radian) report entitled "Heavy-Duty Diesel Vehicle Inspection and Maintenance Study - Volume II - Quantifying the Problem".

Basic Equation

As stated above, the Radian model estimates the effects of nineteen specific instances of tampering and malmaintenance using the following equation:

1. Injection Timing Advanced
2. Injection Timing Retarded
15. Electronics Failed $[(1.0 + \Delta EF_1 + \Delta EF_2 + \Delta EF_{15} + \Delta EF_{16} + \Delta EF_{19}) X]$
16. Electronics Tampered
19. EGR Disabled

3. Minor Injection Problems $(1.0 + \Delta EF_3 + \Delta EF_4) X$
4. Moderate Injection Problems

6. Puff Limiter Mis-Set $(1.0 + \Delta EF_6 + \Delta EF_7) X$
7. Puff Limiter Disabled

8. Maximum Fuel High $(1.0 + \Delta EF_8) X$

9. Clogged Air Filter $(1.0 + \Delta EF_9) X$

10. Wrong/Worn Turbo $(1.0 + \Delta EF_{10}) X$

11. Intercooler Clogged $(1.0 + \Delta EF_{11}) X$

12. Other Air Problems $(1.0 + \Delta EF_{12}) X$

17. Catalytic Converter Removed $(1.0 + \Delta EF_{17} + \Delta EF_{18})] - 1.0 +$
18. Trap Removed/Disabled

5. Severe Injection Problems $+\Delta EF_5$
13. Mechanical Failure $+\Delta EF_{13}$
14. Excess Oil Consumption $+\Delta EF_{14} = \Delta EF_{total}$

The equation accounts for the fact that some failures and/or engine modifications are mutually exclusive. For example, injection timing can not be retarded and advanced on the same vehicle at the same time. The resulting factor, ΔEF_{total} , is the change in the overall fleet average emission factor and is pollutant and weight class (light-heavy, medium-heavy or heavy-heavy) specific. Because the report was prepared for the Air Resources Board in 1987, in EMFAC2000, the methodology was updated to reflect current and projected heavy-duty fleet characteristics. These updates involved revisions to the frequency of occurrence of acts of tampering and malmaintenance of emission control devices, revisions to the projections of the use of emission control devices based on latest engine certification data which also required a change in the assumed future tampering and malmaintenance rate and a change in emissions rates due to emissions control component tampering and malfunction. These changes are described in detail in the following paragraphs.

10.7.1 Estimates of Frequency of Occurrence

1960-1990

Radian estimated the frequency of occurrence of acts of tampering and malmaintenance based upon survey and observation. These estimates were revised by Engine, Fuel and Emissions Engineering, Inc., (EFEE), in a report prepared for the U.S. Environmental Protection Agency entitled "Modeling Deterioration In Heavy-Duty Diesel Particulate Emissions", which was finalized in 1998. The estimates shown in Table 10.7-1 were used for engines built between 1960 through 1987, and 1988 to 1990 in the absence of an enforcement program.

In general, these estimates represent a lower occurrence of tampering and malmaintenance than those originally reported by Radian and used by the Air Resources Board in previous versions of the inventory estimation model. Although the supporting survey information was not made available, little additional information exist and these revised estimates will be used in EMFAC2000.

1991-1997

Because the original report by Radian was completed in 1987, the estimates of the frequency of occurrence of tampering and malmaintenance for 1991 and newer vehicles relied on projections of the use of certain emission control devices to meet more stringent standards. EFEE revisited these assumptions in the report mentioned above based on U.S. EPA certification information. A similar analysis of certification data for model years 1992 to 1998 was performed by the ARB and the alternative estimates are displayed in Table 10.7-2.

Modification to the projections of the use of emission control devices also requires a change in the assumed future tampering rate. Although the tampering and malmaintenance rates originally suggested by Radian were reflective of the fleet as a whole, some suggested occurrences of component malfunction were greater than the

percentage of the fleet so equipped. Table 10.7-3 contrasts the Radian, EFEE and ARB suggested tampering and malmaintenance rates for 1991 to 1993 engines, and for those engines manufactured after 1993.

Table 10.7-1 Frequency of Occurrence of Acts of Tampering and Malmaintenance (Pre 1991)

Frequency of occurrence of acts of tampering and malmaintenance						
DEFECT	HHDT		MHDT		LHDT	
	Pre 88	88-90	Pre 88	88-90	Pre 80	88-90
Timing Advanced	8%	13%	10%	10%	10%	10%
Timing Retarded	15%	12%	6%	6%	10%	10%
Minor Injector Problem	20%	20%	20%	20%	20%	20%
Mod. Injector Problem	10%	10%	10%	10%	10%	10%
Severe Injector Problem	3%	3%	3%	3%	5%	5%
Puff Limiter Misset	29%	23%	18%	18%	2%	5%
Puff Limiter Disabled	30%	23%	15%	15%	1%	3%
Max Fuel High	24%	18%	14%	14%	15%	15%
Clogged Air Filter	22%	20%	23%	19%	21%	19%
Wrong/Worn Turbo	12%	10%	10%	9%	5%	5%
Intercooler Clogged	3%	7%	1%	4%	0%	4%
Other Air Problem	15%	15%	14%	12%	9%	12%
Engine Mech. Failure	2%	2%	2%	2%	3%	3%
Excess Oil Cons.	2%	2%	3%	3%	5%	5%
Electronics Failed	0%	2%	0%	0%	0%	0%
Electronics Tampered	0%	0%	0%	0%	0%	0%
Cat Removed	0%	0%	0%	0%	0%	0%
EGR Stuck Open	0%	0%	0%	0%	0%	0%
EGR Disabled	0%	0%	0%	0%	0%	0%

Table 10.7-2 Percent of Fleet Equipped with Emission Control Devices

Percent of Fleet Equipped with Emission Control Device						
Weight Class	Radian	EFEE	ARB	Radian	EFEE	ARB
	1991-93	1991-93	1991-93		1994-97	1994-97
Turbocharging						
Heavy-Heavy	100%	100%	67%	100%	100%	100%
Medium-Heavy	100%	100%	67%	100%	100%	100%
Light-Heavy	100%	10%	67%	100%	100%	100%
Catalytic Converter						
Heavy-Heavy	40%	0.3%	0%	0%	0%	0%
Medium-Heavy	50%	0.2%	0%	0%	60%	68%
Light-Heavy	50%	0%	0%	0%	80%	70%
Exhaust Gas Recirculation						
Heavy-Heavy	0%	0%	0%	0%	0%	0%
Medium-Heavy	10%	0%	0%	20%	0%	0%
Light-Heavy	20%	0%	0%	30%	0%	19%
Particulate Trap						
Heavy-Heavy	10%	0%	0%	100%	0%	0%
Medium-Heavy	30%	0%	0%	100%	0%	0%
Light-Heavy	50%	0%	0%	100%	0%	0%

Table 10.7-3 Frequency of Occurrence of Acts of Tampering and Malmaintenance (1991-93)

Frequency of Occurrence 1991-1993									
DEFECT	HHDT			MHDT			LHDT		
	Radian	EFEE	ARB	Radian	EFEE	ARB	Radian	EFEE	ARB
Timing Advanced	5%	11%	11%	5%	10%	10%	5%	10%	10%
Timing Retarded	3%	9%	9%	4%	6%	6%	4%	10%	6%
Minor Injector Problem	15%	20%	15%	15%	20%	15%	15%	20%	15%
Mod. Injector Problem	10%	10%	10%	10%	10%	10%	10%	10%	10%
Severe Injector Problem	4%	3%	3%	5%	3%	3%	5%	5%	3%
Puff Limiter Misset	2%	16%	16%	2%	17%	17%	2%	2%	5%
Puff Limiter Disabled	5%	16%	16%	4%	14%	14%	4%	4%	3%
Max Fuel High	3%	13%	13%	2%	14%	14%	5%	14%	14%
Clogged Air Filter	8%	18%	15%	10%	19%	15%	10%	19%	15%
Wrong/Worn Turbo	5%	9%	5%	5%	5%	5%	7%	10%	5%
Intercooler Clogged	5%	6%	5%	3%	5%	5%	3%	5%	5%
Other Air Problem	8%	8%	8%	8%	8%	8%	8%	8%	8%
Engine Mech. Failure	2%	2%	2%	2%	2%	2%	2%	3%	2%
Excess Oil Cons.	5%	2%	5%	8%	3%	5%	10%	5%	5%
Electronics Failed	5%	3%	3%	8%	0%	3%	8%	0%	3%
Electronics Tampered	15%	5%	5%	10%	0%	5%	7%	0%	5%
Cat Removed	8%	6%	0%	8%	0%	0%	8%	0%	0%
EGR Stuck Open	4%	0%	0%	9%	0%	0%	15%	0%	0%
EGR Disabled	0%	0%	0%	3%	0%	0%	6%	0%	0%

Table 10.7-3 Frequency of Occurrence of Acts of Tampering and Malmaintenance (1994-97)

Frequency of Occurrence 1994-97									
DEFECT	HHDT			MHDT			LHDT		
	Radian	EFEE	ARB	Radian	EFEE	ARB	Radian	EFEE	ARB
Timing Advanced	5%	3%	5%	5%	10%	5%	5%	6%	5%
Timing Retarded	3%	3%	3%	4%	5%	3%	4%	6%	3%
Minor Injector Problem	15%	20%	15%	15%	20%	15%	15%	20%	15%
Mod. Injector Problem	10%	10%	10%	10%	10%	10%	10%	10%	10%
Severe Injector Problem	4%	3%	3%	5%	3%	3%	5%	5%	3%
Puff Limiter Misset	0%	4%	4%	0%	15%	4%	2%	1%	4%
Puff Limiter Disabled	0%	4%	4%	0%	13%	4%	4%	2%	4%
Max Fuel High	3%	3%	3%	2%	12%	3%	5%	7%	3%
Clogged Air Filter	8%	16%	15%	10%	18%	15%	10%	15%	15%
Wrong/Worn Turbo	5%	8%	5%	5%	5%	5%	7%	9%	5%
Intercooler Clogged	5%	5%	5%	3%	5%	5%	3%	5%	5%
Other Air Problem	8%	8%	8%	8%	8%	8%	8%	8%	8%
Engine Mech. Failure	2%	2%	2%	2%	2%	2%	2%	3%	2%
Excess Oil Cons.	5%	2%	5%	8%	3%	5%	10%	5%	5%
Electronics Failed	5%	5%	3%	8%	2%	3%	8%	4%	3%
Electronics Tampered	15%	10%	5%	10%	1%	5%	7%	3%	5%
Cat Removed	0%	0%	0%	0%	6%	6%	0%	8%	6%
EGR Stuck Open	40%	0%	0%	30%	0%	0%	30%	0%	0%
EGR Disabled	0%	0%	0%	6%	0%	0%	9%	0%	0%

1998+

Based on experience gained through malfunctioning and tampering rates of emissions related components of light duty vehicles, staff assumed a lower rate of occurrence for most of the 1998 plus defects as shown in Table 10.7-4.

**Table 10.7-4 Frequency of Occurrence of Acts of Tampering and Malmaintenance
(1998-2002 and 2002+)**

DEFECT	HHDT		MHDT		LHDT	
	1998-02	2002+	1998-02	2002+	1998-02	2002+
Timing Advanced	2%	2%	2%	2%	2%	2%
Timing Retarded	2%	2%	2%	2%	2%	2%
Minor Injector Problem	15%	8%	15%	8%	15%	8%
Mod. Injector Problem	10%	5%	10%	5%	10%	5%
Severe Injector Problem	3%	0%	3%	0%	3%	0%
Puff Limiter Misset	0%	0%	0%	0%	0%	0%
Puff Limiter Disabled	0%	0%	0%	0%	0%	0%
Max Fuel High	0%	0%	0%	0%	0%	0%
Clogged Air Filter	15%	15%	15%	15%	15%	15%
Wrong/Worn Turbo	5%	5%	5%	5%	5%	5%
Intercooler Clogged	5%	5%	5%	5%	5%	5%
Other Air Problem	8%	8%	8%	8%	8%	8%
Engine Mech. Failure	2%	2%	2%	2%	2%	2%
Excess Oil Cons.	3%	3%	3%	3%	3%	3%
Electronics Failed	3%	3%	3%	3%	3%	3%
Electronics Tampered	5%	5%	5%	5%	5%	5%
Cat Removed	0%	0%	1%	1%	1%	1%
EGR Stuck Open	0%	0%	0%	0%	0%	0%
EGR Disabled	0%	10%	0%	10%	0%	10%

10.7.2 Emission Increases Due to Tampering

For each incidence of tampering and malmaintenance, Radian estimated a change in the basic emission rate. These estimates were based on engine dynamometer data where tests were performed with and without the malfunction present. Tables 10.7-6, 10.7-7 and 10.7-8 list the Radian estimates of emissions impact, suggested modification to the particulate emissions impacts by EFEE and those to be used in EMFAC2000.

Table 10.7-6 Percent Change in Individual Vehicle Emission Factor

Percent Change in Individual Vehicle Emission Factor												
Radian Report												
DEFECT	Oxides of Nitrogen				Hydrocarbons				Particulate			
	60-87	88-90	91-93	94+	60-87	88-90	91-93	94+	60-87	88-90	91-93	94+
Timing Advanced	70	50	60	60	0	0	30	30	-25	-20	0	0
Timing Retarded	-20	-20	-20	-20	50	50	50	50	50	25	100	100
Minor Injector Problem	0	0	0	0	10	10	20	20	35	35	70	70
Mod. Injector Problem	-5	-5	-5	-5	150	150	300	300	200	200	400	400
Severe Injector Problem	-10	-10	-10	-10	500	500	1100	1100	700	700	1500	4200
Puff Limiter Misset	0	0	0	0	0	0	0	0	20	20	50	50
Puff Limiter Disabled	0	0	0	0	-20	-20	0	0	50	50	100	100
Max Fuel High	10	10	10	10	0	0	0	0	20	30	30	30
Clogged Air Filter	0	0	0	0	0	0	0	0	40	40	50	50
Wrong/Worn Turbo	0	0	0	0	0	0	0	0	40	40	50	50
Intercooler Clogged	20	20	20	20	-20	-20	-20	-20	40	40	50	50
Other Air Problem	0	0	0	0	0	0	0	0	40	40	40	40
Engine Mech. Failure	-10	-10	-10	-10	200	200	300	500	150	150	300	500
Excess Oil Cons.	0	0	0	0	300	300	300	300	120	150	300	600
Electronics Failed	0	0	0	0	0	30	50	50	0	30	60	60
Electronics Tampered	0	50	80	80	0	0	0	0	0	0	50	50
Cat Removed	0	0	0	0	0	0	100	0	0	0	40	0
EGR Stuck Open	0	0	0	0	0	0	40	100	0	0	200	300

Table 10.7-7 Percent Change in Individual Vehicle Emission Factor

Table 10.7-8 Percent Change in Individual Vehicle PM Emission Factor

DEFECT	Percent Change in Individual Vehicle PM Emission Factor									
	EFEE				EMFAC2000					
	60-87	88-90	91-93	94+	Pre 88	88-90	91-93	94-97	98-02	2002+
Timing Advanced	-25	-20	0	0	-25	-20	0	0	0	0
Timing Retarded	50	25	100	100	50	25	100	100	100	100
Minor Injector Problem	35	35	70	70	75	104	104	347	347	347
Mod. Injector	200	200	400	600	75	104	104	347	347	347
Severe Injector Problem	500	700	3200	3200	654	104	104	347	347	347
Puff Limiter Misset	20	20	50	50	20	20	50	50	50	50
Puff Limiter Disabled	50	50	100	100	50	50	100	100	100	100
Max Fuel High	20	30	30	30	20	30	30	30	30	30
Clogged Air Filter	40	40	50	50	40	40	50	50	50	50
Wrong/Worn Turbo	40	40	50	50	40	40	50	50	50	50
Intercooler Clogged	40	40	50	50	40	40	50	50	50	50
Other Air Problem	40	40	40	40	40	40	40	40	40	40
Engine Mech. Failure	150	150	300	500	150	150	300	500	500	500
Excess Oil Cons.	120	150	300	600	120	150	300	600	600	600
Electronics Failed	0	30	60	60	0	30	60	60	60	60
Electronics Tampered	0	0	50	100	0	0	50	50	50	50
Cat Removed	0	0	40	40	0	0	40	40	40	40
EGR Stuck Open	N/A	N/A	N/A	N/A	0	0	200	300	300	300
EGR Disabled	0	0	0	0	0	0	0	0	0	-30

The most significant difference between the impacts suggested by EFEE and those to be used in EMFAC2000 are in the area of the effects of injector problems. To derive the estimates to be used in EMFAC2000, staff analyzed the raw test data used by Radian in the original report and emissions test performed during the CIFER project. As shown in Table 10.7-9, six heavy-duty engines ranging from 1966 to 1975 were tested with either one or two leaking injectors. ARB staff utilized the average emissions increase for five of the six engines (no particulate matter results were reported for one engine) to represent the effect of severe injector problems on pre-1980 engines. Data as shown in Table 10.7-10 from the CIFER project was used to represent the effect of moderate and minor injector problems on pre-1980 engines. Similarly, the CIFER data was used for post 1980 engines. The ratio of the standards was used to adjust this estimate for 1991-1993 and 1994 and newer engines. Similar adjustments were made to the assumed effect on other pollutants.

Table 10.7-9 Emissions Data (g/mile) from Radian Report

MY	Comment	HC	CO	NOx	PM	Fuel
1971	Tuneup Leaking Inj	8.31 35.19	87.56 175.5	35.14 32.23	6.7 32.22	3.19 2.91
		26.88 323%	87.94 100%	-2.91 -8%	25.52 381%	-0.28 -9%
1966	Tuneup Leaking Inj	8.96 41.00	16.19 129.70	62.89 61.41	3.02 34.43	3.45 3.14
		32.04 358%	113.51 701%	-1.48 -2%	31.41 1040%	-0.31 -9%
1969	Baseline 3 Bad Inj	7.89 45.57	31.07 118.00	38.43 33.40	4.31 28.94	3.83 3.50
		37.68 478%	86.93 280%	-5.03 -13%	24.63 571%	-0.33 -9%
1969	Tune Up Orig Air 2 leaking 1 Plugged 2 leaking 1 Plugged	12.78 43.44 38.26	42.19 147.60 152.10	50.26 50.74 47.48	4.91 34.20 36.70	3.80 3.30 3.30
		28.07 220%	107.66 255%	-1.15 -2%	30.54 622%	-0.50 -13%
1966	After Tuneup New Air 1 leaking Inj	11.70 39.75	40.81 138.40	54.46 49.52	4.12 31.04	3.48 3.35
		28.05 240%	97.59 239%	-4.94 -9%	26.92 653%	-0.13 -4%
	Minimum Average Maximum	220% 324% 478%	100% 315% 701%	-13% -7% -2%	381% 654% 1040%	-13% -9% -4%
	Minimum Average Maximum	26.88 30.54 37.68	86.93 98.73 113.51	-5.03 -3.10 -1.15	24.63 27.80 31.41	-0.50 -0.31 -0.13

Source: Table 6-3 from the report entitled “Heavy-Duty Diesel Vehicle Inspection and Maintenance Study – Volume II – Quantifying the Problem”; prepared by Radian Corporation in 1987.

Table 10.7-10 Emissions Data (g/mi) from U.S. EPA - CIFER

ID	Mileage (miles)	GVW (lb)	Test Weight (lb)	Model Year	Engine Model	Test Cycle	Comment	HC	NOx, IV	NOx, Bag	CO	CO2	PM	
1	86671	25000	20000	1995	Navistar X4L	HDTT	As is new injector	43.608 2.392 1723%	15.338 15.380 0%	14.962 15.040 -1%	28.871 12.314 134%	1958.04 1707.59 15%	5.290 1.184 347%	
5	160817	80000	39000	1989	Cum NTC315	HDTT	As is 6 new injectors	2.654 2.222 19%	20.383 21.509 -5%	19.508 21.074 -7%	58.817 44.473 32%	2373.88 2297.75 3%	6.989 5.842 20%	
10 14a	191525	80000	52000	1989	Cum NTC315	HDTT	New fuel pump New #3 injector	58.891 2.809 1997%	26.237 25.374 3%	25.187 24.812 2%	79.180 20.225 291%	2624.57 2578.88 2%	15.472 5.385 187%	
12	119280	54000	43000	1987	DT466	HDTT	As is Rebuilt injectors	1.841 1.287 43%	26.627 29.699 -10%	25.922 29.153 -11%	41.220 38.869 6%	2327.11 2064.97 13%	4.688 3.975 18%	
				1989	Average				686%	-4%	-6%	110%	6%	75%
									1008%	-1%	-2.96%	162%	2.5%	103.5%

Source: U.S. EPA – Test program entitled “105 Grant to Quantify Emission Benefits of Opacity Testing and Repair for HDDV – FY98” conducted by Colorado Institute for Fuels and Engine Research (CIFER), in collaboration with the Denver Regional Air Quality Council (RAQC) and the Colorado Department of Public Health and Environment (CDPHE).

10.8 Application of Deterioration Factors

Most of the emissions deterioration suggested by the Radian model can be attributed to wear as opposed to deliberate acts of tampering. Given this fact and under the assumption that most maintenance related problems would be corrected upon engine rebuild, ARB staff modified its previous deterioration methodology. Essentially it is assumed that the fleet average emissions would peak just before and engine rebuild and achieve its lowest level just afterward.

Because the ARB is utilizing chassis dynamometer data from randomly selected in-use vehicles as the basis for the revisions to the heavy-duty emission factors to be included in EMFAC2000, it was assumed that these engines were nominally half way between engine rebuilds. Given this assumption, the chassis dynamometer data used to revise the basic emission rates are most representative the half way point between the Radian model's prediction of tampering and malmaintenance and tampering alone.

In other words, it is assumed that the Radian model predicts emissions at their highest levels, prior to rebuild. To establish the lower boundary, the model was rerun zeroing out

the effects of engine malfunction. In the alternative scenario, the following ten parameters were mitigated:

- 1) Minor Injector Problems
- 2) Moderate Injector Problems
- 3) Severe Injector Problems
- 4) Clogged Air Filter
- 5) Wrong/Worn Turbo
- 6) Intercooler Clogged
- 7) Other Air Problems
- 8) Engine Mechanical Failure
- 9) Excess Oil Consumption
- 10) Electronics Failed

The resulting change in emissions are shown in Table 10.8-1.

Using the proposed methodology, the zero mile emission rate would be calculated as:

$$ZM = ER / (1 + (EI_1 + EI_2) / 2)$$

The deterioration rate (grams per mile per 10,000 miles) would be calculated as

$$DR = (ER - ZM) / (\text{Odometer} / 10000)$$

Where ZM is the emission rate at zero miles.

ER is the average emission rate of the chassis dynamometer data.

EI₁ is the emissions impact prediction of the Radian model assuming both tampering and malmaintenance.

EI₂ is the emissions impact prediction of the Radian model assuming the effects of tampering "only".

Odometer is the average odometer reading assumed for vehicles by model year.

Tables 10.8-2, 10.8-3, 10.8-4 and 10.8-5 show the zero-mile emission and deterioration rates respectively for California HHDTs, California MHDTs, California LHDTs and federal HHDTs.

Table 10.8-1 Percent Change in Fleet Average Emission Factor

Heavy-Heavy Diesel Trucks												
	Oxides Of Nitrogen				Hydrocarbon				Particulate Matter			
	Pre88	88-90	91-93	94-97	98-02	2002+	Pre88	88-90	91-93	94-97	98-02	2002+
Tampering and Maintenance	3.4	5.5	9.8	7.6	5.6	5.8	226.9	343.7	332.1	525.8	512.4	240.9
Tamper Only	5.1	6.0	10.2	6.7	4.8	4.8	1.1	1.1	7.8	3.0	1.6	1.6
Average	4.2	5.7	10.0	7.1	5.2	5.3	114.0	172.4	170.0	264.4	257.0	121.3
Medium-Heavy Diesel Trucks												
	Oxides Of Nitrogen				Hydrocarbon				Particulate Matter			
	Pre88	88-90	91-93	94-97	98-02	2002+	Pre88	88-90	91-93	94-97	98-02	2002+
Tampering and Maintenance	5.2	4.2	10.0	7.6	5.6	5.8	227.6	342.1	325.9	525.8	512.4	240.9
Tamper Only	7.3	5.3	10.3	6.7	4.8	4.8	-0.1	-0.1	6.0	3.0	1.6	1.6
Average	6.2	4.7	10.1	7.1	5.2	5.3	113.8	171.0	165.9	264.4	257.0	121.3
Light-Heavy Diesel Trucks												
	Oxides Of Nitrogen				Hydrocarbon				Particulate Matter			
	Pre88	88-90	91-93	94-97	98-02	2002+	Pre88	88-90	91-93	94-97	98-02	2002+
Tampering and Maintenance	4.0	3.3	10.0	7.6	5.6	5.8	257.6	388.0	325.9	525.8	512.4	240.9
Tamper Only	6.6	4.5	10.3	6.7	4.8	4.8	4.8	4.4	6.0	3.0	1.6	1.6
Average	5.3	3.9	10.1	7.1	5.2	5.3	131.2	196.2	165.9	264.4	257.0	121.3

Table 10.8-2 Zero-Mile Emission (ZM) and Deterioration (DR) Rates – HHDT

Zero-Mile Emission (g/mi) and Deterioration Rates (g/mi per 10000 mi)								
California - Heavy-Heavy-Diesel Trucks								
MY GROUP	HC		CO		NOX		PM	
	ZM	DR	ZM	DR	ZM	DR	ZM	DR
Pre 1975	1.60	0.018	8.36	0.095	28.52	0.012	1.98	0.016
1975-76	1.45	0.018	7.81	0.098	27.17	0.013	1.85	0.016
1977-79	1.45	0.019	7.81	0.101	27.17	0.013	1.85	0.017
1980-83	1.45	0.020	7.81	0.108	27.17	0.014	1.85	0.018
1984-86	0.74	0.011	4.87	0.074	20.18	0.011	1.18	0.012
1987-90	0.34	0.009	2.48	0.065	16.79	0.015	0.84	0.008
1991-93	0.28	0.009	1.74	0.056	15.97	0.030	0.51	0.009
1994-97	0.19	0.016	0.84	0.068	19.06	0.042	0.32	0.010
1998	0.18	0.014	0.63	0.049	23.01	0.037	0.26	0.007
1999-02	0.18	0.009	0.63	0.031	13.36	0.013	0.21	0.003
2003	0.14	0.003	1.01	0.023	6.68	0.007	0.26	0.003
2004	0.14	0.003	1.01	0.023	6.68	0.007	0.26	0.003

Table 10.8-3 Zero-Mile Emission (ZM) and Deterioration (DR) Rates – MHDT

Zero-Mile Emission (g/mi) and Deterioration Rates (g/mi per 10000 mi)								
California – Medium-Heavy-Diesel Trucks								
MY GROUP	HC		CO		NOX		PM	
	ZM	DR	ZM	DR	ZM	DR	ZM	DR
Pre 1975	0.34	0.011	3.17	0.100	18.50	0.032	1.07	0.016
1975-76	0.34	0.011	3.17	0.100	18.50	0.032	1.07	0.016
1977-79	0.34	0.011	3.17	0.100	18.50	0.032	1.07	0.016
1980-83	0.34	0.011	3.17	0.100	18.50	0.032	1.07	0.016
1984-86	0.33	0.014	2.99	0.131	17.91	0.043	1.00	0.021
1987-90	0.21	0.016	1.80	0.140	15.74	0.034	0.73	0.017
1991-93	0.18	0.018	1.43	0.139	13.11	0.078	0.45	0.022
1994-97	0.11	0.017	0.78	0.121	11.55	0.048	0.27	0.018
1998	0.09	0.014	0.64	0.097	10.52	0.032	0.24	0.012
1999-02	0.09	0.014	0.64	0.097	10.52	0.032	0.24	0.012
2003	0.09	0.007	1.04	0.074	5.79	0.018	0.29	0.009
2004+	0.09	0.006	1.04	0.074	5.48	0.017	0.29	0.009

Table 10.8-4 Zero-Mile Emission (ZM) and Deterioration (DR) Rates – LHDT

MY GROUP	BAG 1 Rates						BAG 2 Rates									
	ZM	HC	CO	ZM	DR	NOX	ZM	DR	PM	ZM	DR	NOX	ZM	DR	PM	
Pre 1975	0.28	0.010	0.90	0.031	3.51	0.005	0.43	0.006	0.19	0.007	0.74	0.025	3.94	0.005	0.23	0.003
1975-76	0.28	0.011	0.90	0.035	3.51	0.005	0.43	0.006	0.19	0.007	0.74	0.028	3.94	0.006	0.23	0.003
1977-79	0.28	0.012	0.90	0.036	3.51	0.006	0.43	0.007	0.19	0.008	0.74	0.030	3.94	0.006	0.23	0.003
1980-83	0.28	0.013	0.90	0.040	3.51	0.006	0.43	0.007	0.19	0.009	0.74	0.033	3.94	0.007	0.23	0.004
1984-86	0.28	0.014	0.90	0.046	3.51	0.007	0.43	0.008	0.19	0.010	0.74	0.037	3.94	0.008	0.23	0.004
1987-90	0.22	0.020	0.70	0.063	3.55	0.006	0.44	0.009	0.15	0.013	0.57	0.051	3.99	0.007	0.23	0.005
1991-93	0.18	0.013	0.83	0.063	6.40	0.029	0.10	0.003	0.22	0.016	0.68	0.052	6.67	0.031	0.07	0.002
1994	0.13	0.016	0.61	0.073	6.58	0.021	0.08	0.004	0.16	0.019	0.50	0.060	6.86	0.022	0.05	0.003
1995	0.13	0.016	0.61	0.073	6.58	0.021	0.08	0.004	0.16	0.019	0.50	0.060	6.86	0.022	0.05	0.003
1996-97	0.13	0.016	0.61	0.073	6.58	0.021	0.08	0.004	0.16	0.019	0.50	0.060	6.86	0.022	0.05	0.003
1998-99	0.03	0.003	0.54	0.063	2.17	0.005	0.06	0.002	0.02	0.002	0.44	0.052	2.43	0.006	0.03	0.001
2000-01	0.03	0.003	0.54	0.063	2.17	0.005	0.06	0.002	0.02	0.002	0.44	0.052	2.43	0.006	0.03	0.001
2002-03	0.04	0.002	0.87	0.048	1.39	0.003	0.07	0.002	0.03	0.001	0.71	0.039	1.56	0.004	0.04	0.001
2004+	0.03	0.002	0.87	0.048	1.39	0.003	0.07	0.002	0.02	0.001	0.71	0.039	1.56	0.004	0.04	0.001

Table 10.8-5 Zero-Mile Emission (ZM) and Deterioration (DR) Rates – MHDT

Zero-Mile Emission (g/mi) and Deterioration Rates (g/mi per 10000 mi)								
Federal - Heavy-Heavy-Diesel Trucks								
MY GROUP	HC		CO		NOX		PM	
	ZM	DR	ZM	DR	ZM	DR	ZM	DR
Pre 1974	1.60	0.018	8.37	0.094	27.98	0.017	2.29	0.012
1974-78	1.60	0.020	8.37	0.105	27.98	0.019	2.29	0.014
1979-83	1.45	0.020	7.81	0.107	26.66	0.020	2.14	0.014
1984-87	0.74	0.011	4.87	0.075	19.81	0.017	1.36	0.010
1988-90	0.35	0.009	2.50	0.066	16.96	0.012	0.91	0.007
1991-93	0.29	0.009	1.76	0.055	15.95	0.031	0.53	0.008
1994-97	0.19	0.016	0.84	0.068	19.06	0.042	0.31	0.010
1998	0.18	0.014	0.63	0.049	23.01	0.037	0.26	0.007
1999-02	0.18	0.009	0.63	0.031	13.36	0.013	0.21	0.003
2003	0.14	0.003	1.01	0.023	6.68	0.007	0.26	0.003
2004+	0.14	0.003	1.01	0.023	6.68	0.007	0.26	0.003

Tables 10.8-6 to 10.8-9 show a comparison of emission factors at a cumulative mileage of 100,000 miles between EMFAC2000 and MVEI7G. For heavy-heavy and medium-heavy diesel trucks, the HC and CO emissions are in general lower in EMFAC2000 than in MVEI7G while NOx emissions are higher. PM emissions for newer model years are higher in EMFAC2000. For light-heavy diesel trucks, the Bag1 and Bag2 HC, CO, NOx and PM emissions factors are in general lower in EMFAC2000.

Table 10.8-6 HHD Gram per Mile Emissions at 100,000 Miles
MVEI7G v EMFAC2000

Model Year	Heavy-Heavy Diesel Trucks							
	EMFAC2000				MVEI7G			
	HC	CO	NOX	PM	HC	CO	NOX	PM
Pre 1975	1.776	9.307	28.635	2.135	3.866	14.710	23.351	2.171
1975-76	1.630	8.781	27.295	2.013	3.866	14.710	23.351	2.171
1977	1.637	8.818	27.300	2.019	3.734	14.710	23.208	2.171
1978	1.637	8.818	27.300	2.019	3.605	14.203	22.408	2.096
1979	1.637	8.818	27.300	2.019	3.551	14.203	22.349	2.096
1980-83	1.650	8.888	27.309	2.031	3.551	14.203	22.349	2.096
1984	0.848	5.607	20.298	1.300	2.666	13.695	13.941	2.021
1985-86	0.848	5.607	20.298	1.300	2.341	13.695	13.941	2.021
1987	0.434	3.131	16.939	0.926	2.341	13.695	13.941	1.564
1988-89	0.434	3.131	16.939	0.926	2.288	13.383	13.881	1.296
1990	0.434	3.131	16.939	0.926	2.288	13.383	11.291	1.296
1991-93	0.372	2.295	16.274	0.600	1.615	9.838	10.132	0.808
1994-95	0.353	1.525	19.479	0.418	0.983	11.304	10.119	0.259
1996-97	0.353	1.525	19.479	0.418	0.946	10.885	9.744	0.250
1998	0.324	1.122	23.379	0.325	0.946	10.885	7.795	0.250
1999-02	0.269	0.933	13.494	0.243	0.946	10.885	7.795	0.250
2003	0.176	1.245	6.743	0.284	0.946	10.885	7.795	0.250
2004	0.176	1.245	6.743	0.284	0.946	10.885	7.795	0.250

Table 10.8-7 MHDT Gram per Mile Emissions at 100,000 Miles
MVEI7G v EMFAC2000

Model Year	Medium-Heavy Diesel Trucks							
	EMFAC2000				MVEI7G			
	HC	CO	NOX	PM	HC	CO	NOX	PM
Pre 1975	0.448	4.178	18.823	1.239	3.760	13.024	19.318	2.302
1975-76	0.448	4.178	18.823	1.239	3.760	13.024	19.318	2.302
1977-79	0.448	4.178	18.823	1.239	3.577	13.024	19.149	2.302
1980-83	0.448	4.178	18.823	1.239	3.577	13.024	19.149	2.302
1984-86	0.469	4.303	18.343	1.212	2.446	13.024	9.490	2.302
1987	0.377	3.197	16.078	0.905	2.446	13.024	9.490	1.587
1988-90	0.377	3.197	16.078	0.905	2.065	11.604	9.099	1.305
1991-93	0.359	2.821	13.890	0.666	1.583	9.012	8.805	0.726
1994-97	0.276	1.993	12.037	0.452	0.962	10.199	8.707	0.266
1998	0.238	1.617	10.844	0.359	0.962	10.199	6.966	0.266
1999-02	0.238	1.617	10.844	0.359	0.962	10.199	6.966	0.266
2003	0.162	1.780	5.967	0.383	0.962	10.199	6.966	0.266
2004+	0.156	1.780	5.655	0.383	0.962	10.199	6.966	0.266

**Table 10.8-8 LHDT – BAG1 Gram per Mile Emissions at 100,000 Miles
MVEI7G v EMFAC2000**

Model Year	Light-Heavy Diesel Trucks							
	EMFAC2000 - BAG 1				MVEI7G			
	HC	CO	NOX	PM	HC	CO	NOX	PM
Pre 1975	0.383	1.209	3.715	0.584	2.846	10.830	13.611	1.275
1975-76	0.394	1.245	3.721	0.592	2.846	10.830	13.611	1.275
1977-79	0.400	1.263	3.724	0.596	2.708	10.830	13.492	1.275
1980-81	0.412	1.299	3.730	0.604	2.708	10.830	13.492	1.275
1982-83	0.412	1.299	3.730	0.604	2.548	10.193	12.699	1.200
1984-86	0.429	1.354	3.739	0.616	1.742	10.193	6.293	1.200
1987	0.420	1.327	3.779	0.642	1.742	10.193	6.293	1.197
1988-90	0.420	1.327	3.779	0.642	1.489	8.708	6.325	1.051
1991-93	0.311	1.457	6.911	0.120	1.010	6.153	5.967	0.563
1994	0.285	1.334	7.012	0.108	0.652	7.445	5.949	0.222
1995	0.285	1.334	7.012	0.108	0.380	7.445	5.179	0.222
1996-97	0.285	1.334	7.012	0.108	0.110	7.445	4.412	0.222
1998-99	0.065	1.172	2.318	0.096	0.110	7.445	4.412	0.222
2000-01	0.065	1.172	2.318	0.096	0.110	7.445	4.412	0.222
2002-03	0.058	1.353	1.485	0.105	0.080	7.445	3.393	0.222
2004+	0.048	1.353	1.485	0.105	0.072	7.445	2.824	0.222

**Table 10.8-8 LHDT – BAG2 Gram per Mile Emissions at 100,000 Miles
MVEI7G v EMFAC2000**

Model Year	Light-Heavy Diesel Trucks							
	EMFAC2000 - BAG 2				MVEI7G			
	HC	CO	NOX	PM	HC	CO	NOX	PM
Pre 1975	0.260	0.989	4.158	0.301	2.846	10.830	13.611	1.275
1975-76	0.268	1.019	4.165	0.305	2.846	10.830	13.611	1.275
1977-79	0.271	1.034	4.168	0.307	2.708	10.830	13.492	1.275
1980-81	0.279	1.064	4.175	0.311	2.708	10.830	13.492	1.275
1982-83	0.279	1.064	4.175	0.311	2.548	10.193	12.699	1.200
1984-86	0.291	1.109	4.185	0.317	1.742	10.193	6.293	1.200
1987	0.285	1.086	4.230	0.331	1.742	10.193	6.293	1.197
1988-90	0.285	1.086	4.230	0.331	1.489	8.708	6.325	1.051
1991-93	0.377	1.199	7.259	0.086	1.010	6.153	5.967	0.563
1994	0.346	1.098	7.365	0.077	0.652	7.445	5.949	0.222
1995	0.346	1.098	7.365	0.077	0.380	7.445	5.179	0.222
1996-97	0.346	1.098	7.365	0.077	0.110	7.445	4.412	0.222
1998-99	0.044	0.959	2.595	0.049	0.110	7.445	4.412	0.222
2000-01	0.044	0.959	2.595	0.049	0.110	7.445	4.412	0.222
2002-03	0.039	1.108	1.662	0.054	0.080	7.445	3.393	0.222
2004+	0.033	1.108	1.662	0.054	0.072	7.445	2.824	0.222

10.9 Clean Diesel Effects

In October of 1993, the state of California's clean diesel regulation which reduced the aromatic content of the fuel to 10 percent by volume, and the sulfur content to 0.05 percent by weight, was implemented. The effect of reducing the sulfur and the aromatic content is to reduce particulates (PM) and NO_x emissions. Federal clean diesel fuel, which was also implemented in 1993, has the same sulfur content as California clean diesel (0.05 % by weight) but did not mandate a reduction in aromatic content. The estimated emission reductions for clean diesel fuels to be used in EMFAC2000 were provided by the Stationary Source Division (SSD) of the ARB. SSD staff estimated fuel correction factors based on emissions testing performed on two heavy-duty engines using fuels with different sulfur and aromatic content. Table 10.9-1 and 10.9-2 include the estimated NOx and PM reductions. Post-1993 heavy-duty diesel trucks are certified using federal fuel because federal and California emissions standards are aligned starting 1991. Since federal fuel has only lower sulfur but no mandate for aromatic content, a fuel correction factor due to lower aromatics for NO_x and PM emissions was applied to post-1993 engines certified for sale in California. The South Coast Air Basin (SCAB) and Ventura County previously mandated low sulfur diesel fuel (0.05 % by weight) which has been in use since 1985. Also included in table 10.9-3 are fuel correction factors for SCAB and Ventura county for calendar years 1985 to 1993. For October 1993 and beyond, clean diesel fuel regulations were implemented statewide.

TABLE 10.9-1 Emissions Reduction due to Lower Sulfur and Aromatic Content

Model Year	Reduction Due to Low Sulfur (0.28 to 0.05 % by weight)	Reduction Due to Low Aromatic (30 to 10 % by volume)	Reduction Due to Low Aromatic (30 to 10 % by volume)	Combined Effect of Lower Sulfur and Aromatic Contents
	PM	PM	NOx	PM
Pre 1991	3.86%	16.73%	5.57%	20.59%
1991+	22.70%	10.07%	12.4%	32.77%

Table 10.9-2 Statewide Clean Diesel Fuel Correction Factors for Calendar Years 1993+

MODEL YEAR	NOX	PM
PRE-91	0.944	0.794
1991-93	0.876	0.672
1994+	0.876	0.899

Table 10.9-3 Low sulfur Diesel Fuel Correction Factors for SCAB and Ventura County only

Model Year	CALENDAR YEAR	PM
All	Pre-1985	1.000
Pre-1991	1985-1993	0.961
1991-1993	1985-1993	0.773
All	1994+	Same as statewide

10.10 Idle Emissions from HDDT

For the first time, emissions associated with idle trips are calculated in EMFAC2000. Operators of heavy-duty trucks may run the engine to power accessories or move in queue to pick up or drop off cargo. These engine on, to engine off events with no appreciable distance traveled, are defined as “idle trips”. In EMFAC2000, the idle emissions rates are obtained from emissions testing of light heavy-duty trucks by the U.S. EPA. Table 10.10-1 displays the percent of total HDDT trips that are idle, and the associated idle emission rates. Based on the HDDT activity data collected by the Air Resources Board, about five percent of all HDDT trips are assumed to be idle trips with the exception of heavy-heavy diesels, where twenty six percent of all trips are assumed to be idle trips.

Table 10.10-1 Idle Emission Factors (grams per hour)

Weight Class	Idle Trips (Percent)	Idle Emission Rates (grams per hour)			
		HC	CO	NOx	CO2
LHD	5%	44	247	396	29687
MHD	5%	44	247	396	29687
HHD	26%	44	247	396	29687
LHG	4%	27	155	2	4777
MHG	6%	27	155	2	4777

10.11 Emissions Comparison

Figures 10.11-1 to 10.11-12 show a statewide emissions inventory comparison between MVEI7G and EMFAC2000 (ver. 199f) runs for calendar years 1995, 2000, 2010 and 2020. The effect of revisions to HDDT emissions factors, activity and population distribution are reflected in this charts.

Figure 10.11-1 Statewide NOx Emissions – MVEI7G v EMFAC2000(v199f)
Heavy-Heavy Diesel Trucks

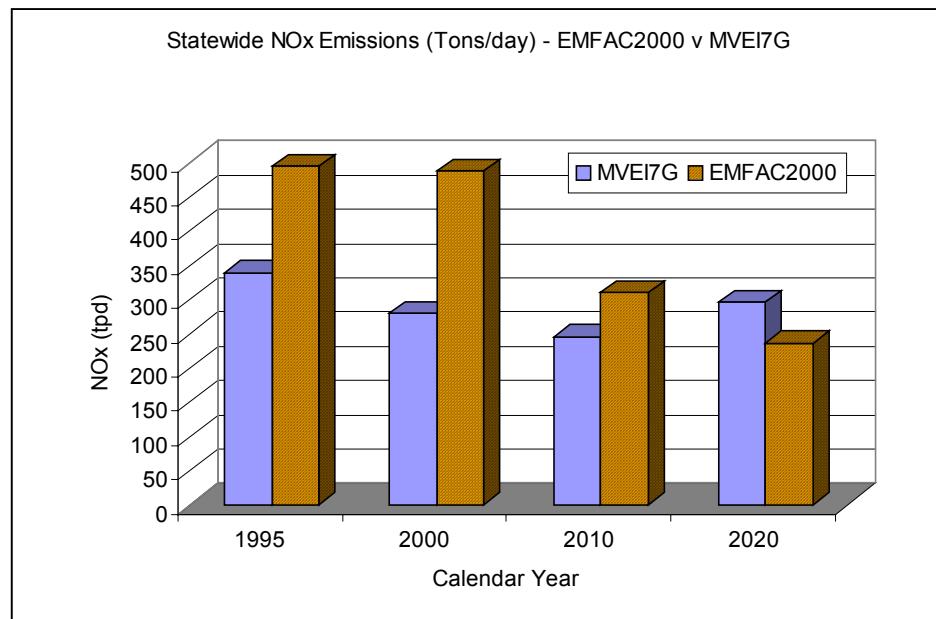


Figure 10.11-2 Statewide PM10 Emissions – MVEI7G v EMFAC2000 (v199f)
Heavy-Heavy Diesel Trucks

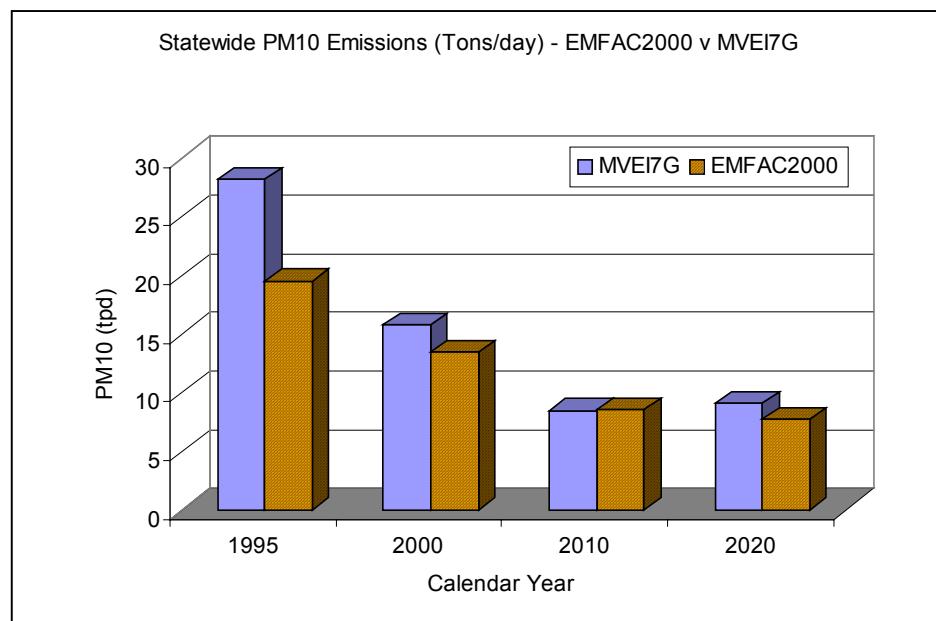


Figure 10.11-3 Statewide TOG Emissions – MVEI7G v EMFAC2000 (v199f)
Heavy-Heavy Diesel Trucks

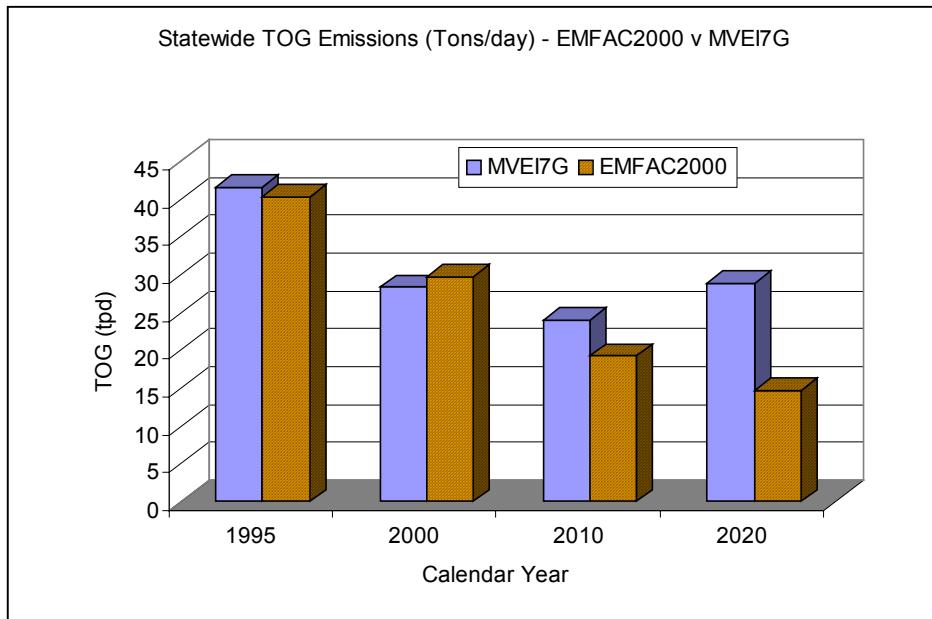


Figure 10.11-4 Statewide CO Emissions – MVEI7G v EMFAC2000 (v199f)
Heavy-Heavy Diesel Trucks

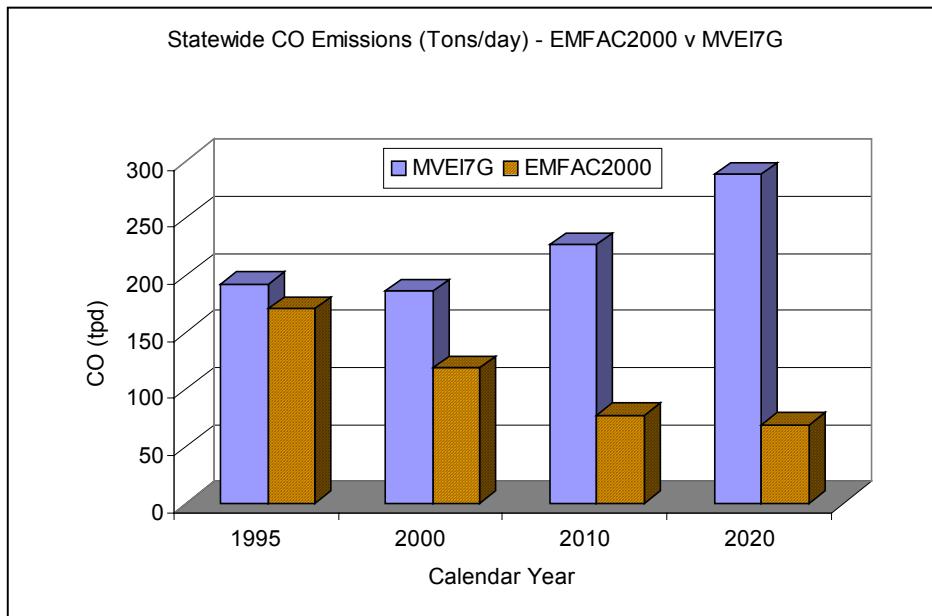


Figure 10.11-5 Statewide NOx Emissions – MVEI7G v EMFAC2000(v199f)
Medium-Heavy Diesel Trucks

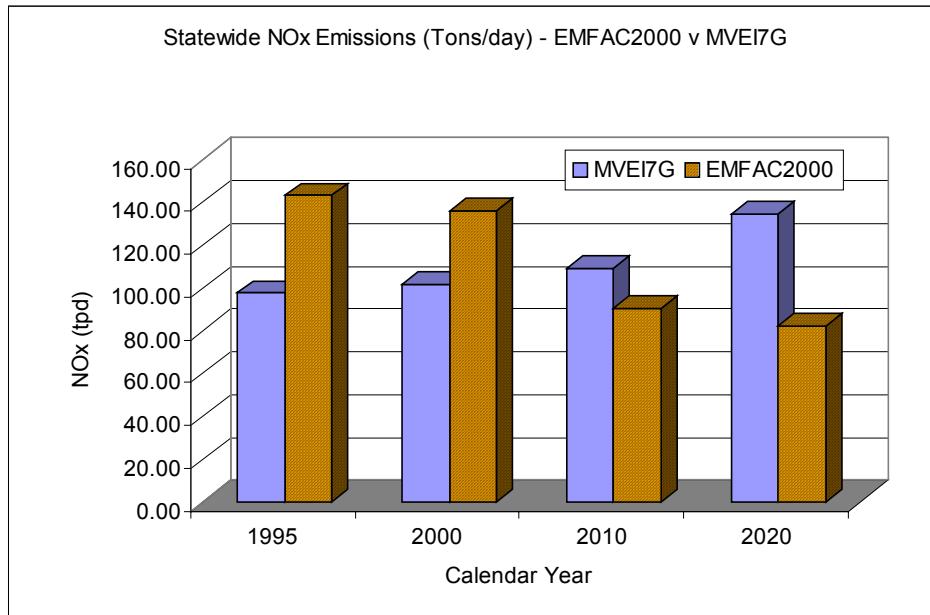


Figure 10.11-6 Statewide PM10 Emissions – MVEI7G v EMFAC2000 (v199f)
Medium-Heavy Diesel Trucks

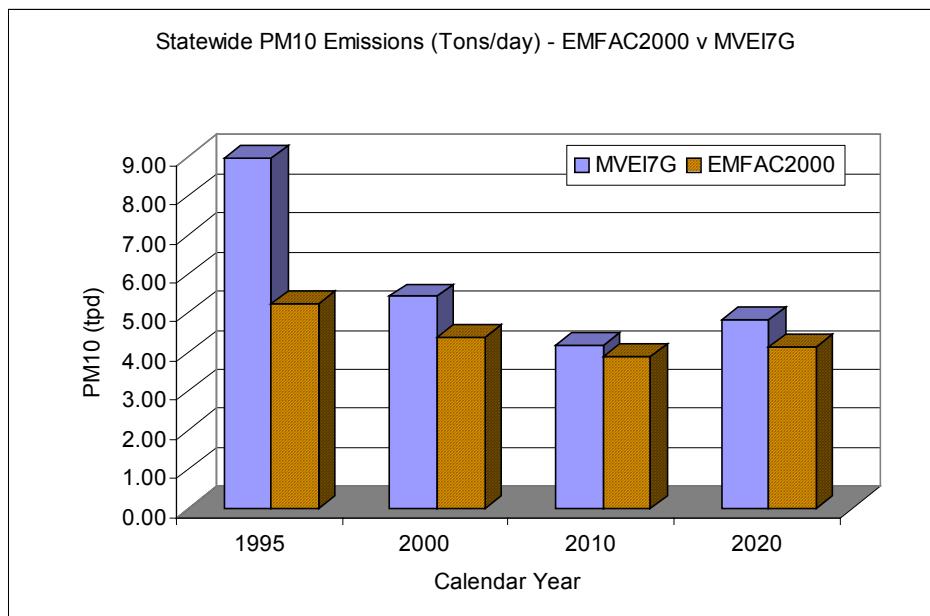


Figure 10.11-7 Statewide TOG Emissions – MVEI7G v EMFAC2000 (v199f)
Medium-Heavy Diesel Trucks

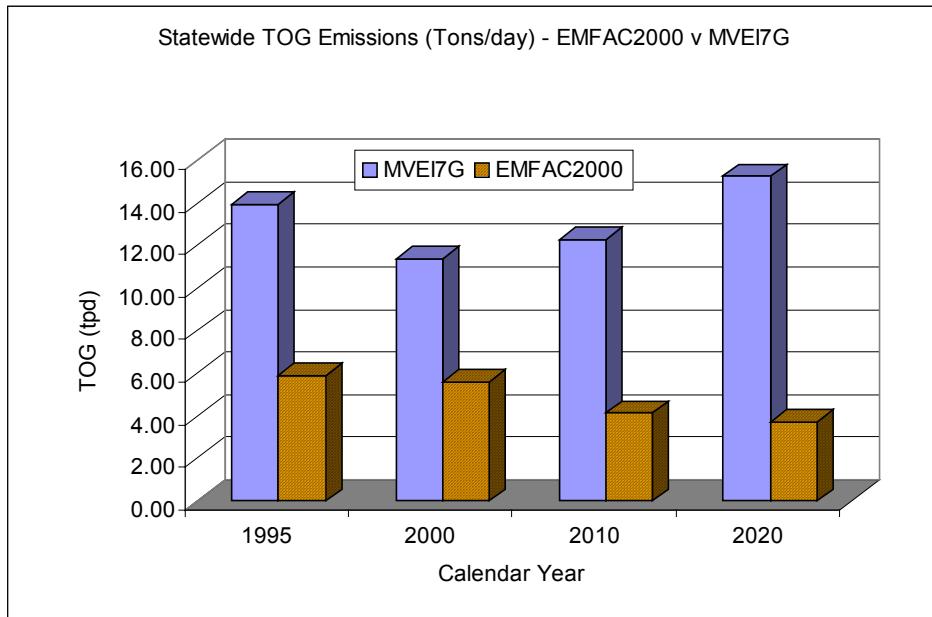


Figure 10.11-8 Statewide CO Emissions – MVEI7G v EMFAC2000 (v199f)
Medium-Heavy Diesel Trucks

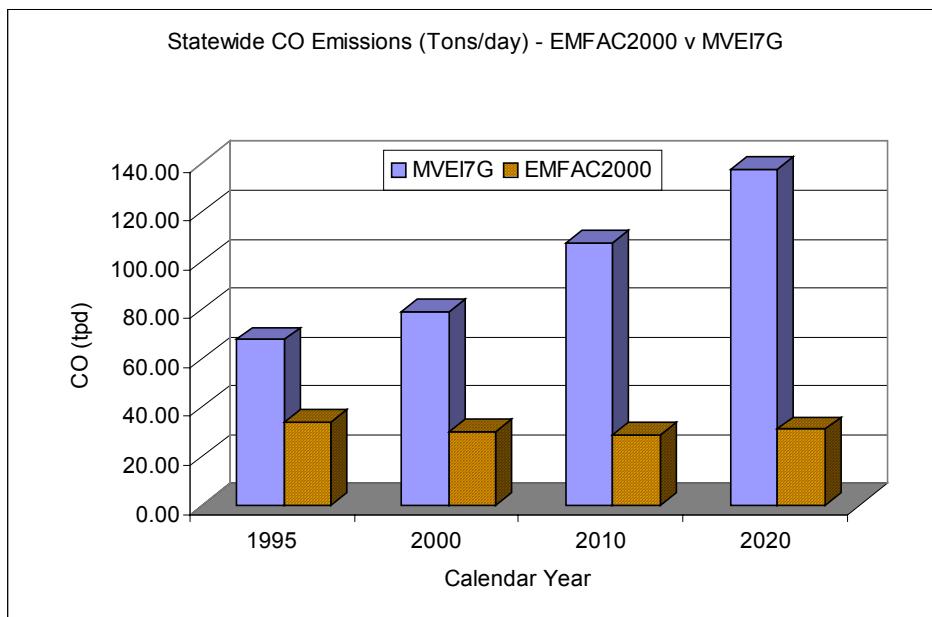


Figure 10.11-9 Statewide NOx Emissions – MVEI7G v EMFAC2000(v199f)
Light-Heavy Diesel Trucks

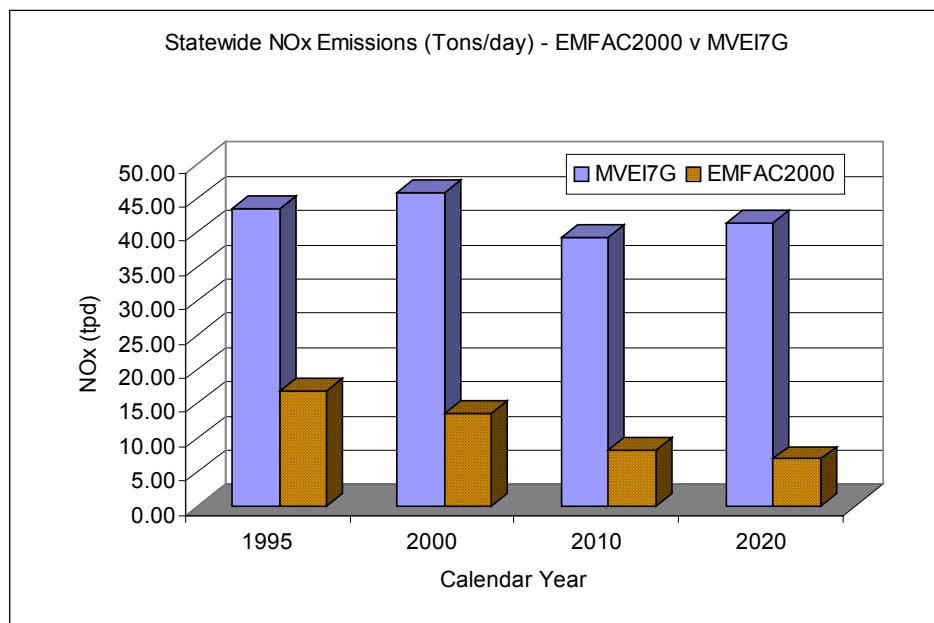


Figure 10.11-10 Statewide PM10 Emissions – MVEI7G v EMFAC2000 (v199f)
Light-Heavy Diesel Trucks

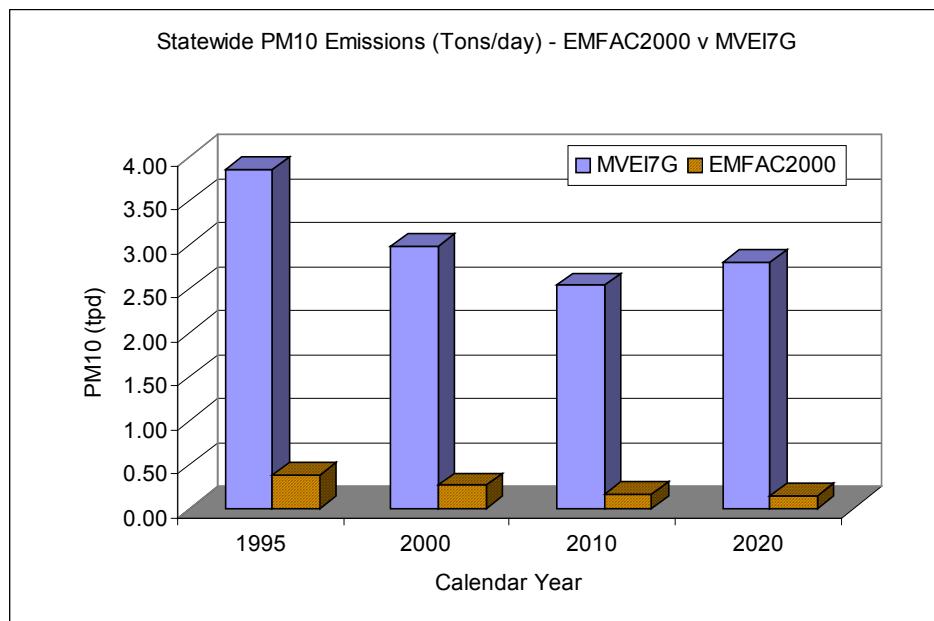


Figure 10.11-11 Statewide TOG Emissions – MVEI7G v EMFAC2000 (v199f)
Light-Heavy Diesel Trucks

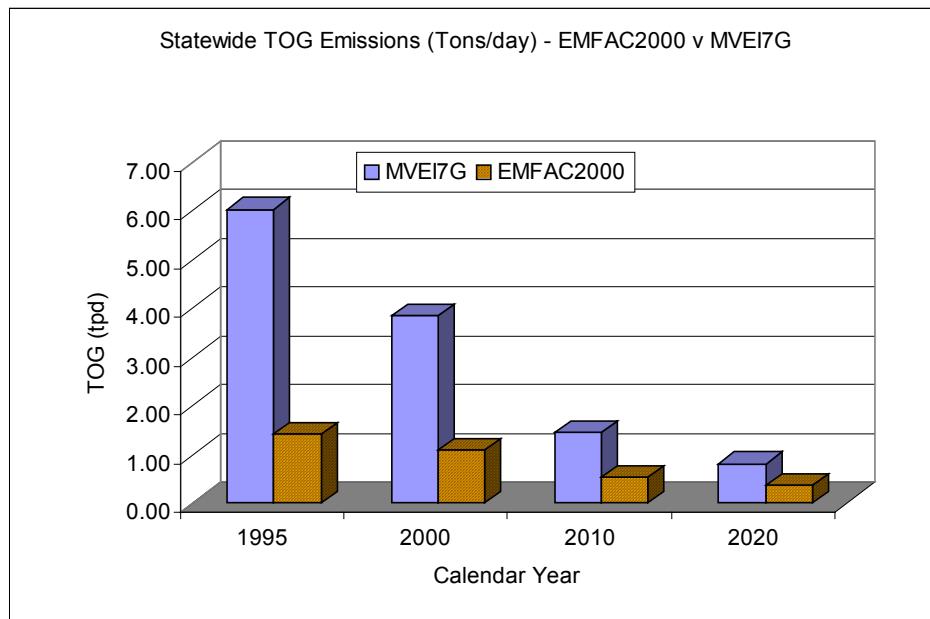
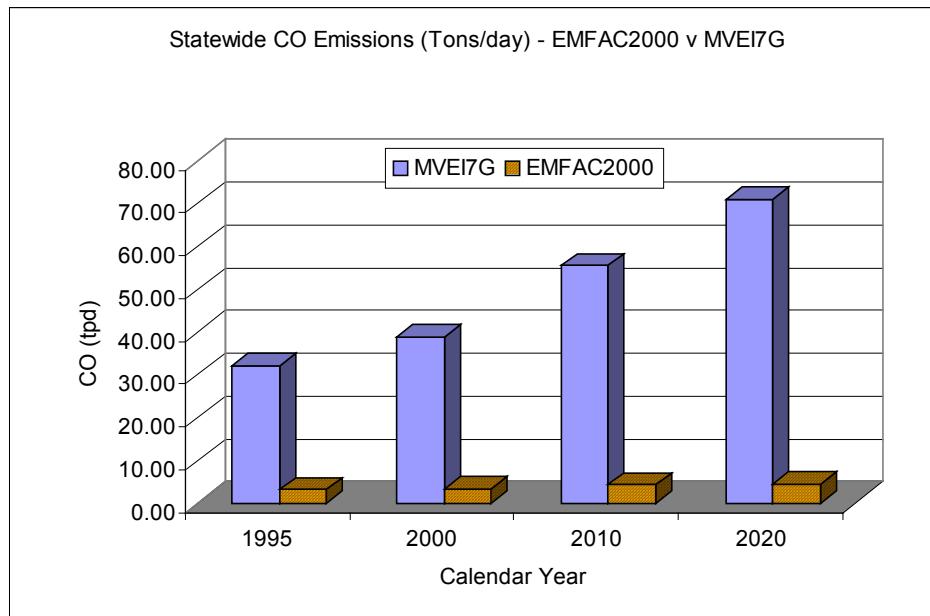


Figure 10.11-12 Statewide CO Emissions – MVEI7G v EMFAC2000 (v199f)
Light-Heavy Diesel Trucks



10.12 Heavy-Duty Gasoline Trucks (HDGT) Emission Factors

Similar to heavy-duty diesel-powered trucks, HDGTs with a gross vehicle weight of 8,501 pounds or greater are classified in the following manner:

Table 10.12-1 Heavy-Duty Gasoline Trucks Weight Class

GVW in lbs	Vehicle Class
8,501 to 14,000	Light-Heavy Duty Trucks (LHGT)
14,001 to 33,000	Medium-Heavy Duty Trucks (MHGT)
> 33,000	Heavy-Heavy Duty Trucks (HHGT)

For heavy-duty gasoline engines, the emissions and deterioration rates are same as those used in EMFAC7G. In EMFAC7G, the heavy-duty gasoline emission factors are based on gram per brake horsepower hour (g/bhp-hr) emission rates derived from engine test data collected from in-use testing and certification test data. The g/bhp-hr emission rates are then converted into grams per mile emission factors using conversion factors defined by the following formula:

$$CF = (\text{Fuel density}) / (\text{BSFC} * \text{MPG})$$

Where CF = conversion factor in bhr-hr/mile

BSFC = brake specific fuel consumption in lb/bhp-hr

MPG = fuel economy in miles per gallon.

The gram per brake horsepower emission and deterioration rates for pre-1998 models remained unchanged from those in EMFAC7F. In 1998 the 4.0 g/bhp-hr standard took effect and in the year 2004 a 2.5 g/bhp-hr NO_x+NMHC standard will be implemented. The emission rates for the 4.0 g/bhp-hr were derived by taking the ratio of the standards and applying them to the 1997 NO_x emission and deterioration rates. For the 2.5 g/bhp-hr NO_x+NMHC standard in 2004, a certification standard of 0.375 g/bhp-hr for NMHC and 2.115 g/bhp-hr for NO_x was assumed. Table 10.12-2 gives the zero mile emission (g/bhp-hr) and deterioration (g/bhp-hr per 10000 miles) rates for heavy-duty gasoline engines.

The weight class specific gram per mile emission rates were calculated by multiplying the g/bhp-hr engine emission rates given in Table 10.12-2 with the weight class specific conversion factors (same as in EMFAC7G) given in Table 10.12-3. The engine deterioration rates are also multiplied by conversion factors to obtain the gram per mile per 10000 miles deterioration rates.

For model years 1995 and beyond, the LHG emission rates take into account the effects of the reclassification of light-heavy-duty gasoline trucks into medium duty trucks (MDV) and the effects of the low emission vehicle regulations. Table 10.12-4 gives the implementation schedule of both the reclassification of light-heavy gasoline trucks into the MDV category and the implementation of the low emission vehicle (LEV) and Ultra

Low Emission Vehicle (ULEV). Table 10.12-5 gives the emission rates associated with these classes of vehicles.

Based on the information provided by various manufacturers, it is believed that 72% of the 1995+ LHGTs are engine certified while the remainder are chassis certified. The base emission rates for chassis certified LHGTs were calculated by taking the ratios of the 1994 medium duty truck standard (trucks with GVW between 6000 to 8500 lbs.) to the 1995 medium duty truck, LEV and ULEV standards applicable to LHGTs and applying them to the 1994 medium duty truck emission rates. The emission rates for engine certified LHGTs were calculated by taking the ratio of the 1994 engine certification standards to the 1995 medium duty truck, LEV and ULEV engine certification standards and applying them to the 1994 LHGT base emission rates.

Table 10.12-6 shows the combined medium duty, LEV and ULEV zero mile emission and deterioration rates for LHGTs while Table 10.12-7 shows zero mile emission and deterioration rates for MHGTs.

Table 10.12-2 Heavy-Duty Gasoline Engine Emissions Rates

Heavy-Duty Gasoline Engine Emission Rates (g/bhp-hr) and Deterioration Rates (g/bhp-hr per 10000 miles)						
Model year	HC		CO		NOx	
	ZM	DR	ZM	DR	ZM	DR
Pre - 1977	5.19	0.18	101.00	4.69	5.00	0.10
1977 - 1984	3.59	0.18	55.95	4.69	4.78	0.10
1985	2.55	0.06	39.90	0.96	3.99	0.10
1986	2.23	0.06	31.39	0.96	3.99	0.10
1987 - 1997	1.00	0.09	13.70	0.60	3.99	0.10
1998+	0.22	0.02	13.70	0.60	1.70	0.04

Table 10.12-3 Heavy-Duty - g/bhp-hr to g/mile - Conversion Factors

Model Year	LHGT	MHGT
Pre 1973	1.0	1.5
1973 – 1988	1.0	1.5
1989 – 1993	0.9	1.5
1994 – 1997	0.9	1.4
1998+	0.9	1.4

Table 10.12-4 Implementation Schedule of LHGT

Implementation Schedule of Light-Heavy-Duty Trucks Sales Fraction by Model Year			
Model Year	MED	LEV	ULEV
1995	1.00	0.00	0.00
1996-2001	0.50	0.50	0.00
2002-2003	0.00	1.00	0.00
2004	0.00	0.00	1.00

Table 10.12-5 Emission Rates for LEV, ULEV and MDV Standard LHGT

Category	HC		CO		NO_x	
	ZM	DR	ZM	DR	ZM	DR
MDV	0.388	0.036	8.893	0.373	1.955	0.058
LEV	0.279	0.026	8.893	0.373	1.447	0.041
ULEV	0.224	0.020	8.893	0.373	1.227	0.036

Table 10.12-6 Zero mile emission and Deterioration Rates - LHGT

Zero mile emission (g/mi) and Deterioration (g/mi per 10k miles) Rates - LHGT								
MODEL YEAR	HC		CO		NO_x		PM	
	ZM	DR	ZM	DR	ZM	DR	ZM	DR
Pre 1977	5.19	0.180	101.00	4.690	5.00	0.100	1.23	0.036
1977-84	3.59	0.180	55.95	4.690	4.78	0.100	1.23	0.036
1985	2.55	0.060	39.90	0.960	3.99	0.100	1.23	0.036
1986	2.23	0.060	31.39	0.960	3.99	0.100	1.23	0.036
1987-88	1.00	0.090	13.70	0.600	3.99	0.100	1.23	0.036
1989-94	0.90	0.081	12.33	0.540	3.59	0.090	1.23	0.036
1995	0.64	0.058	10.61	0.457	2.77	0.074	1.23	0.036
1996-01	0.39	0.036	8.89	0.373	1.95	0.058	1.23	0.036
2002-03	0.28	0.026	8.89	0.373	1.45	0.041	1.23	0.036
2004+	0.22	0.020	8.89	0.373	1.23	0.036	1.23	0.036

Table 10.12-7 Zero mile emission and Deterioration Rates - MHDG

Zero mile emission (g/mi) and Deterioration (g/mi per 10k miles) Rates - MHDG								
MODEL YEAR	HC		CO		NOx		PM	
	ZM	DR	ZM	DR	ZM	DR	ZM	DR
Pre 1977	8.87	0.270	151.50	7.035	7.50	0.150	0.054	0.000
1977-84	5.38	0.270	83.93	7.035	7.17	0.150	0.054	0.000
1985	3.83	0.090	59.85	1.440	5.99	0.150	0.054	0.000
1986	3.34	0.090	47.09	1.440	5.99	0.150	0.054	0.000
1987-93	1.50	0.135	20.55	0.900	5.99	0.150	0.054	0.000
1994-97	1.40	0.126	19.18	0.840	5.59	0.140	0.054	0.000
1998-03	1.40	0.126	19.18	0.840	4.47	0.140	0.054	0.000
2004+	0.31	0.023	19.18	0.840	1.90	0.058	0.054	0.000

10.13 Diesel Urban Bus Emission Factors

In MVEI7G emission factors for diesel urban buses were derived from chassis based emissions test data collected from 1962 to 1990 model year buses tested over the New York Bus Composite Cycle (NYBC). The inertia weight used in this test procedure was 19500 lbs, which is less than the average weight of an empty bus (28,000 lbs). In EMFAC2000, emissions factors were derived from chassis dynamometer based emissions test data obtained from the National Renewable Energy Laboratory (NREL). Under contract to NREL, the West Virginia University, Department of Mechanical and Aerospace Engineering tested buses on the standard Central Business District (CBD) test cycle using various test fuels. The CBD test cycle is part of the Transit Coach Design Operating Duty Cycle (SAE J1376, July 1982) designed to simulate driving conditions experienced by buses during a typical route in a downtown business district. Data from 51 buses tested on the CBD using federal diesel fuel (D2) was obtained from NREL. The test weight used was the curb weight plus half passenger load and the weight of the driver. The test data used to derive the emission factors in MVEI7G were not used in the derivation of new emission factors for EMFAC2000 since the two data sets were obtained from two different test cycles with different inertia weights. The raw data used is shown in Tables 10.13-A1 and 10.13-A2 in the appendix.

10.14 Diesel Urban Bus - Emissions Data Analysis

The emissions data used in this analysis represented diesel transit buses built between 1988 to 1996. Repeat tests were first averaged and the results were then plotted as a function of the model year as shown in Figures 10.14-1 to 10.14-4. The scatter plot was then curve-fit to determine the equation.

Pre-1999 Model Years:-

Using the regression equations, emissions are calculated for each model year that are in the data set range, i.e. between 1988 to 1996. Emission factors for model years prior to 1988 were made equal to the calculated emission factor for 1988, while emission factors for model years 1997 to 1998 were made equal to the calculated emissions for 1996 model year buses. Model years were then grouped together based on California transit bus emissions standards (Table 10.14-A3). An average emission factor was then calculated for each model year group. The results are shown in Table 10.14-1.

The curve for NOx emissions, Figure 10.14-1, shows an increasing trend in NOx emissions for model years between 1992 to 1996 although the emissions standard for NOx goes down from 5 g/bhp-hr in 1991-93 to 4 g/bhp-hr in 1996. An explanation for this is that the CBD test procedure is also capturing some off-cycle NOx emissions. In EMFAC2000, it is assumed that off-cycle NOx will be completely eliminated by 1999.

1999-2007 Model Years:-

For the 1999-02 model year group the NOx and PM emissions were calculated by taking the ratio of the standards between the 1999-02 and the 1991-93 model year groups and multiplying the ratio to the 1991-93 model year emission factors. Because of same emissions standards, the 1999-02 model year HC and CO emissions were assumed to be equal to the 1996-98 model year group. Emissions for 2003+ model year groups were calculated using the ratio of standards relative to the 1991-93 model year group. The resulting emissions by model year group are shown on Table 10.14-1.

2008+ Model Years

Since the new bus rule adopted in February 24, 2000 specifies that 15% of the buses in fleets of more than 200 buses will be zero emission buses (ZEBs), a fleet average emission standard was first calculated in order to determine the ratio of standards between the 2008+ and 1991-93 model years. From a survey of transit bus fleet operators in California conducted by the ARB, the fraction of buses in fleets of more than 200 buses was found to be equal to 0.75. Thus the fraction of buses that are ZEBs is 11% (15% of 0.75). The 2008+ model year fleet average emission standard is then equal to = (2007 emission standard)*0.89. The results of this operation were then used to calculate the ratio of standards between the 2008+ and 1991-93 model year groups.

Figures 10.14-A1 to 10.14-A4 in the appendix show comparison of MVEI7G emissions factors versus EMFAC2000 emissions factors.

10.15 Diesel Urban Bus - Deterioration Rates

In MVEI7G, analysis of emission factors as a function of odometer data showed no significant deterioration of emission control systems for buses. This may be due to the regular maintenance performed by transit bus fleet operators. Based on this finding, in MVEI7G, deterioration rates for all model years were assumed to be zero. The same assumption is also applied in EMFAC2000. Therefore, zero mile emission rates for buses were made equal to the average emission rates calculated above.

Table 10.14-1 Diesel Urban Bus - NOx Emissions in g/mi

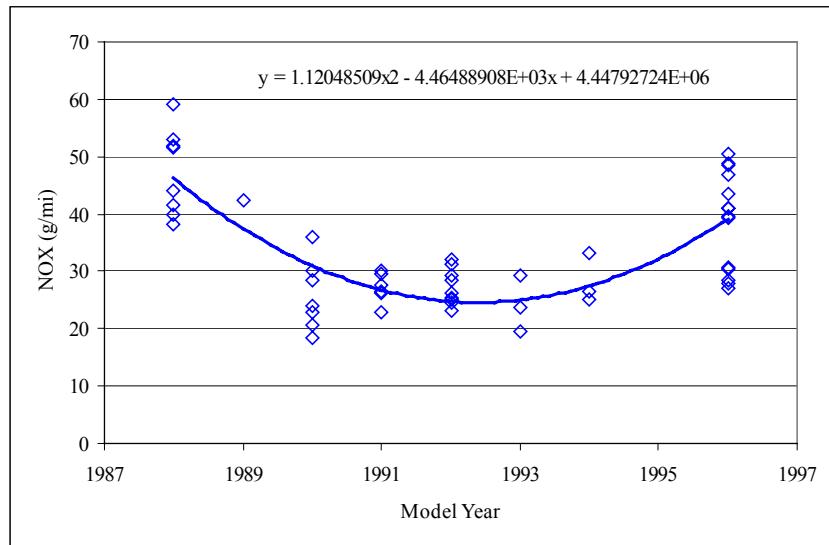


Table 10.14-2 Diesel Urban Bus - PM Emissions in g/mi

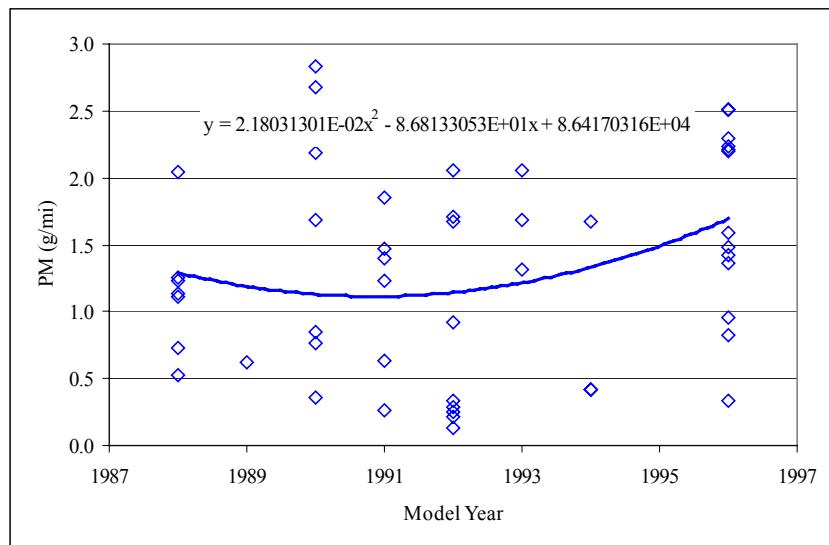


Table 10.14-3 Diesel Urban Bus - HC Emissions in g/mi

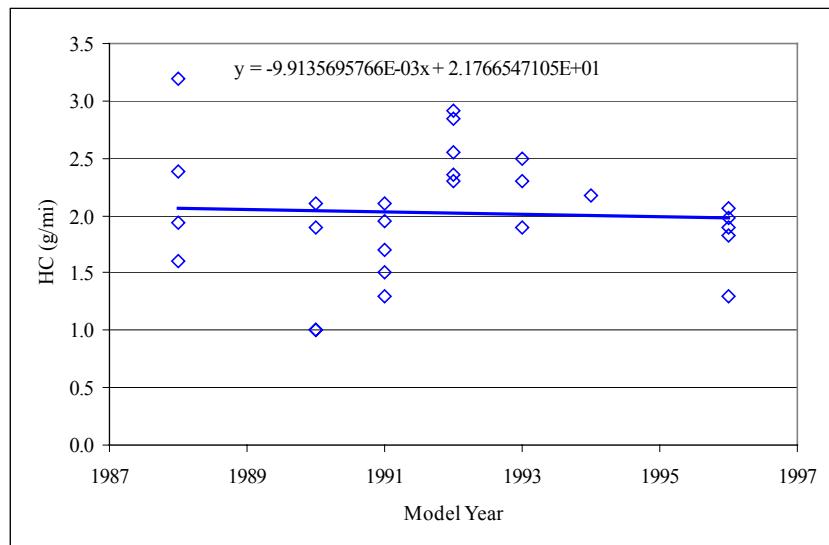


Table 10.14-4 Diesel Urban Bus - CO Emissions in g/mi

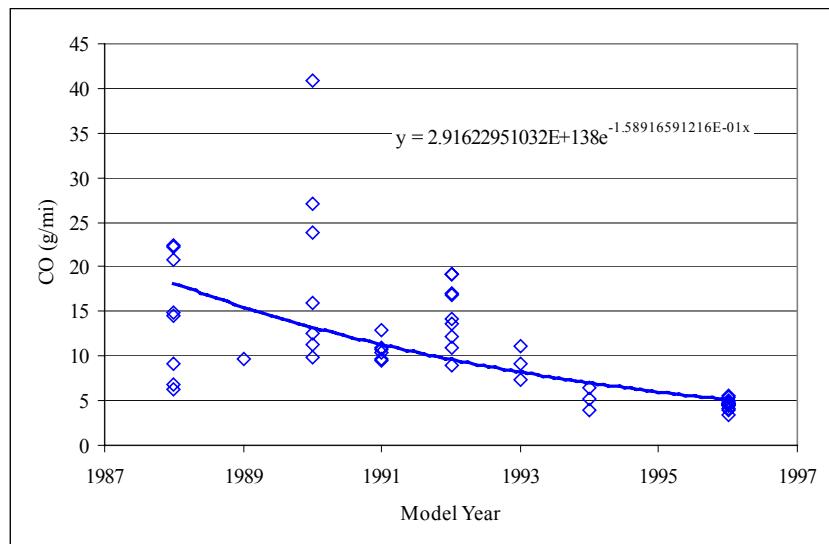


Table 10.14-1 Diesel Urban Bus Emission Factors

Model Year	HC	CO	NOX	PM
	g/mile			
PRE 1987	2.06	18.19	46.18	1.29
1987-90	2.05	16.28	40.20	1.22
1991-93	2.02	9.71	25.49	1.16
1994-95	1.99	6.50	29.84	1.41
1996-98	1.98	5.10	39.17	1.69
1999-02	1.98	5.10	20.39	0.58
2003	0.84	4.05	10.20	0.12
2004-06	0.84	4.05	2.55	0.12
2007	0.84	4.05	1.02	0.12
2008	0.75	4.05	0.90	0.10

Table 10.1-A1 Raw Data from New York Department of Energy and Conservation¹

Vehicle ID	Engine Type	Model Year	Make	GVW (lb)	Test Weight (lb)	Odometer (miles)	Replicate Test	THC g/mi	CO mg/mi	NOX mg/mi	PM mg/mi	CO2 g/mi	Fuel Economy (mpg)
1	Caterpillar 3116	1997	GMC	33000	23100	3500	FALSE	0.08	4.93	16.60	600	1976	4.86
1	Caterpillar 3116	1997	GMC	33000	23100	3500	TRUE	0.15	5.53	16.90	470	2011	4.77
1	Caterpillar 3116	1997	GMC	33000	23100	3500	TRUE	0.19	6.21	17.60	500	1996	4.80
1	Caterpillar 3116	1997	GMC	33000	23100	3500	TRUE	0.12	6.80	17.20	550	2026	4.73
1	Caterpillar 3116	1997	GMC	33000	23100	3500	TRUE	0.12	5.24	.	440	1957	4.90
2	Caterpillar 3208	1989	FORD	33000	23100	66300	FALSE	0.63	6.09	18.80	1840	1601	5.98
2	Caterpillar 3208	1989	FORD	33000	23100	66300	TRUE	0.60	6.05	20.50	1660	1654	5.79
2	Caterpillar 3208	1989	FORD	33000	23100	66300	TRUE	0.71	5.87	20.50	1730	1656	5.78
2	Caterpillar 3208	1989	FORD	33000	23100	66300	TRUE	0.57	5.46	20.80	1560	1599	5.99
2	Caterpillar 3208	1989	FORD	33000	23100	66300	TRUE	0.60	5.51	20.50	1520	1624	5.90
3	Caterpillar 3116	1990	GMC	30000	21000	11623	FALSE	0.81	3.35	14.00	.	1580	6.07
3	Caterpillar 3116	1990	GMC	30000	21000	11623	TRUE	0.80	3.26	14.00	1750	1608	5.97
3	Caterpillar 3116	1990	GMC	30000	21000	11623	TRUE	0.79	3.05	13.80	1510	1582	6.07
4	Caterpillar 3208	1985	FORD	50000	27000	42985	FALSE	1.66	11.70	20.50	1950	2292	4.16
4	Caterpillar 3208	1985	FORD	50000	27000	42985	TRUE	1.66	10.30	20.60	1580	2290	4.17
4	Caterpillar 3208	1985	FORD	50000	27000	42985	TRUE	1.49	9.70	20.40	1370	2259	4.23
4	Caterpillar 3208	1985	FORD	50000	27000	42985	TRUE	1.47	9.70	20.70	1360	2211	4.32
5	Cummins B5.9-190	1995	FORD	26000	18200	26100	FALSE	0.15	2.33	12.10	380	1356	7.09
5	Cummins B5.9-190	1995	FORD	26000	18200	26100	TRUE	0.13	2.03	11.90	320	1338	7.18
5	Cummins B5.9-190	1995	FORD	26000	18200	26100	TRUE	0.13	2.27	11.40	340	1346	7.14
6	Cummins B5.9-190	1994	FORD	31000	21000	8900	FALSE	0.25	1.65	14.10	.	1561	6.16
6	Cummins B5.9-190	1994	FORD	31000	21000	8900	TRUE	0.25	1.56	14.00	410	1537	6.26
6	Cummins B5.9-190	1994	FORD	31000	21000	8900	TRUE	0.28	1.54	13.80	330	1559	6.17
6	Cummins B5.9-190	1994	FORD	31000	21000	8900	TRUE	0.27	1.47	13.90	290	1520	6.33
7	Cummins C8.3-210	1993	FORD	36000	25200	2600	FALSE	1.00	2.87	11.20	920	1812	5.30
7	Cummins C8.3-210	1993	FORD	36000	25200	2600	TRUE	1.00	2.90	11.30	670	1818	5.28
7	Cummins C8.3-210	1993	FORD	36000	25200	2600	TRUE	1.13	2.96	11.40	630	1821	5.27
8	Cummins C8.3-225	1996	FORD	33000	23100	8300	FALSE	0.53	1.93	15.30	890	1885	5.10
8	Cummins C8.3-225	1996	FORD	33000	23100	8300	TRUE	0.52	1.89	15.40	760	1883	5.11
8	Cummins C8.3-225	1996	FORD	33000	23100	8300	TRUE	0.49	1.71	15.30	640	1847	5.21
8	Cummins C8.3-225	1996	FORD	33000	23100	8300	TRUE	0.48	1.60	15.20	590	1792	5.37
9	Cummins C8.3-225	1996	FORD	33000	23100	9400	FALSE	0.51	2.70	15.10	830	1744	5.51
9	Cummins C8.3-225	1996	FORD	33000	23100	9400	TRUE	0.52	2.53	15.50	780	1773	5.42
9	Cummins C8.3-225	1996	FORD	33000	23100	9400	TRUE	0.62	2.38	15.90	750	1757	5.47
9	Cummins C8.3-225	1996	FORD	33000	23100	9400	TRUE	0.55	2.37	16.20	720	1764	5.45
9	Cummins C8.3-225	1996	FORD	33000	23100	9400	FALSE	0.56	2.78	16.50	900	1737	5.53
9	Cummins C8.3-225	1996	FORD	33000	23100	9400	TRUE	0.73	2.67	16.30	790	1800	5.34
9	Cummins C8.3-225	1996	FORD	33000	23100	9400	TRUE	0.59	2.34	16.30	700	1807	5.32

¹A test program entitled “Characterization and Control of Heavy-Duty Vehicle Emissions in the New York Metropolitan Area”, conducted by West Virginia University for Energy and Environmental Analysis under contract to the New York State of Environmental Conservation and Energy.

Table 10.1-A1 Raw Data from New York Department of Energy and Conservation (Contd.)

Vehicle ID	Engine Type	Model	Year	Make	GVW (lb)	Test Weight (lb)	Odometer (miles)	Replicate Test	THC	CO	NOX	PM mg/mi	CO2 g/mi	Fuel Economy (mpg)
10	Cummins HTC-300	1984	FORD	66000	42000	275851	FALSE	1.74	5.36	27.90	1600	2167	4.42	
10	Cummins HTC-300	1984	FORD	66000	42000	275851	TRUE	1.56	5.17	27.70	1570	2184	4.39	
10	Cummins HTC-300	1984	FORD	66000	42000	275851	TRUE	1.68	5.47	29.10	1550	2193	4.37	
11	Cummins L-10	1996	NAVISTAR	32000	28000	73393	FALSE	3.29	6.96	11.10	1410	1420	6.69	
11	Cummins L-10	1996	NAVISTAR	32000	28000	73393	TRUE	3.32	6.56	11.10	1320	1463	6.50	
11	Cummins L-10	1996	NAVISTAR	32000	28000	73393	TRUE	2.96	6.08	11.00	1180	1420	6.70	
12	Cummins L-10	1994	INT.HARV	65000	42000	87319	FALSE	2.75	5.52	16.50	1120	2011	4.75	
12	Cummins L-10	1994	INT.HARV	65000	42000	87319	TRUE	2.63	5.08	16.90	1000	1995	4.79	
12	Cummins L-10	1994	INT.HARV	65000	42000	87319	TRUE	2.40	5.18	16.90	950	1996	4.79	
12	Cummins L-10	1994	INT.HARV	65000	42000	87319	TRUE	2.78	5.10	16.90	900	2032	4.71	
12	Cummins L-10	1994	INT.HARV	65000	50000	87319	FALSE	2.93	4.93	16.70	1210	2148	4.45	
12	Cummins L-10	1994	INT.HARV	65000	50000	87319	TRUE	2.77	5.08	17.00	1010	2181	4.39	
12	Cummins L-10	1994	INT.HARV	65000	50000	87319	TRUE	2.91	4.95	17.50	1010	2160	4.43	
12	Cummins L-10	1994	INT.HARV	65000	27000	87319	FALSE	2.83	4.41	13.10	900	1767	5.41	
12	Cummins L-10	1994	INT.HARV	65000	27000	87319	TRUE	2.89	4.25	13.50	1050	1727	5.53	
12	Cummins L-10	1994	INT.HARV	65000	27000	87319	TRUE	3.05	4.38	13.60	1030	1705	5.60	
13	Cummins M-11	1998	NAVISTAR	32000	36400	43000	FALSE	0.55	3.01	14.70	790	1733	5.54	
13	Cummins M-11	1998	NAVISTAR	32000	36400	43000	TRUE	0.54	3.31	15.30	610	1754	5.48	
13	Cummins M-11	1998	NAVISTAR	32000	36400	43000	TRUE	0.56	3.18	15.10	520	1699	5.65	
14	Cummins M11-280E	1998	HEIL	65098	42000	10100	FALSE	0.70	2.75	38.00	660	2850	3.37	
14	Cummins M11-280E	1998	HEIL	65098	42000	10100	TRUE	0.64	2.77	37.00	600	2890	3.33	
14	Cummins M11-280E	1998	HEIL	65098	42000	10100	TRUE	0.62	2.63	37.10	590	2882	3.34	
15	Cummins M11-280E	1998	FREIGHTLINER	41500	29050	800	FALSE	0.57	2.02	24.60	510	2326	4.14	
15	Cummins M11-280E	1998	FREIGHTLINER	41500	29050	800	TRUE	0.55	2.07	24.90	440	2353	4.09	
15	Cummins M11-280E	1998	FREIGHTLINER	41500	29050	800	TRUE	0.54	2.08	22.70	450	2256	4.26	
15	Cummins M11-280E	1998	FREIGHTLINER	41500	29050	800	TRUE	0.58	2.09	21.70	400	2193	4.39	
15	Cummins M11-280E	1998	FREIGHTLINER	41500	29050	800	TRUE	0.54	2.12	23.10	410	2231	4.31	
16	Cummins M11-330E	1995	FREIGHTLINER	31020	21700	113300	FALSE	0.63	2.62	15.30	670	1433	6.70	
16	Cummins M11-330E	1995	FREIGHTLINER	31020	21700	113300	TRUE	0.60	2.55	15.90	570	1435	6.69	
16	Cummins M11-330E	1995	FREIGHTLINER	31020	21700	113300	TRUE	0.64	2.67	17.70	510	1433	6.70	
16	Cummins M11-330E	1995	FREIGHTLINER	31020	21700	113300	TRUE	0.63	2.95	14.80	540	1444	6.65	
17	Detroit Diesel Corp. Series 50	1966	INT.HARV	85000	48000	353000	FALSE	0.05	10.35	28.10	540	2461	3.89	
17	Detroit Diesel Corp. Series 50	1966	INT.HARV	85000	48000	353000	TRUE	0.04	9.05	31.30	500	2376	4.03	
17	Detroit Diesel Corp. Series 50	1966	INT.HARV	85000	48000	353000	TRUE	0.09	9.44	30.10	400	2323	4.12	
18	Ford FM07 BEPCS	1988	FORD	26500	18550	199600	FALSE	0.99	4.87	21.20	960	1570	6.10	
18	Ford FM07 BEPCS	1988	FORD	26500	18550	199600	TRUE	0.91	5.01	21.10	900	1639	5.84	
18	Ford FM07 BEPCS	1988	FORD	26500	18550	199600	TRUE	0.90	4.39	20.30	950	1582	6.06	
18	Ford FM07 BEPCS	1988	FORD	26500	18550	199600	TRUE	0.87	5.03	19.70	910	1560	6.14	

Table 10.1-A1 Raw Data from New York Department of Energy and Conservation (Contd.)

Vehicle ID	Engine Type	Model Year	Make	GVW (lb)	Test Weight (lb)	Odometer (miles)	Replicate Test	THC	CO	NOX	PM ng/mi	CO2 g/mi	Fuel Economy (mpg)
19	Ford KFM07-8FPEZ	1989	FORD	52000	36400	32900	FALSE	1.44	6.81	18.90	3090	2580	3.71
19	Ford KFM07-8FPEZ	1989	FORD	52000	36400	32900	TRUE	1.31	6.30	18.40	2210	2493	3.85
19	Ford KFM07-8FPEZ	1989	FORD	52000	36400	32900	TRUE	1.31	6.14	18.00	1900	2509	3.82
19	Ford KFM07-8FPEZ	1989	FORD	52000	52000	32900	FALSE	1.42	6.79	20.30	2190	2861	3.35
19	Ford KFM07-8FPEZ	1989	FORD	52000	52000	32900	TRUE	1.31	6.50	21.00	2040	2870	3.34
19	Ford KFM07-8FPEZ	1989	FORD	52000	52000	32900	TRUE	1.31	6.41	20.60	2090	2835	3.38
19	Ford KFM07-8FPEZ	1989	FORD	52000	26000	32900	FALSE	1.25	5.50	15.90	1620	2286	4.20
19	Ford KFM07-8FPEZ	1989	FORD	52000	26000	32900	TRUE	1.22	5.49	16.20	1440	2313	4.15
19	Ford KFM07-8FPEZ	1989	FORD	52000	26000	32900	TRUE	1.23	5.60	16.50	1710	2209	4.34
20	Ford LFM078EPC7	1990	FORD	24500	17150	17596	FALSE	0.69	2.30	12.20	850	1164	8.24
20	Ford LFM078EPC7	1990	FORD	24500	17150	17596	TRUE	0.68	2.24	12.20	720	1146	8.37
20	Ford LFM078EPC7	1990	FORD	24500	17150	17596	TRUE	0.70	2.24	12.90	740	1172	8.19
20	Ford LFM078EPC7	1990	FORD	24500	17150	17596	TRUE	0.72	2.45	13.20	760	1171	8.19
20	Ford LFM078EPC7	1990	FORD	24500	17150	17596	TRUE	0.77	2.46	12.30	760	1156	8.29
21	GMC V8-8.2	1988	GMC	35000	24500	35586	FALSE	0.77	7.59	13.70	2830	2048	4.67
21	GMC V8-8.2	1988	GMC	35000	24500	35586	TRUE	0.78	7.21	13.50	2360	2033	4.71
21	GMC V8-8.2	1988	GMC	35000	24500	35586	TRUE	0.72	7.07	13.90	2170	1995	4.80
22	International 165F	1987	INT.HARV	26500	18550	19600	FALSE	0.95	3.76	19.60	1950	1400	6.84
22	International 165F	1987	INT.HARV	26500	18550	19600	TRUE	0.95	3.77	19.70	1870	1395	6.87
22	International 165F	1987	INT.HARV	26500	18550	19600	TRUE	0.91	3.56	20.40	1610	1359	7.05
23	MACK E7-250	1997	MACK	60420	42294	4800	FALSE	0.27	1.96	20.30	1650	2619	3.68
23	MACK E7-250	1997	MACK	60420	42294	4800	TRUE	0.23	1.74	20.70	550	2599	3.70
23	MACK E7-250	1997	MACK	60420	42294	4800	TRUE	0.24	1.83	20.60	420	2611	3.69
23	MACK E7-250	1997	MACK	60420	42294	4800	FALSE	0.27	1.85	20.80	400	2643	3.64
24	MACK E7-250	1985	VOLVO	27500	19250	286400	FALSE	0.74	13.50	23.10	1220	1140	8.29
24	MACK E7-250	1985	VOLVO	27500	19250	286400	TRUE	0.68	12.70	22.70	1010	1155	8.19
24	MACK E7-250	1985	VOLVO	27500	19250	286400	TRUE	0.70	12.50	22.80	1000	1161	8.15
24	MACK E7-250	1985	VOLVO	27500	19250	286400	TRUE	0.69	11.60	21.70	870	1094	8.65
24	MACK E7-250	1985	VOLVO	27500	19250	286400	TRUE	0.64	13.20	21.20	1000	1116	8.47
25	MACK EM7-275	1998	MACK	68420	47894	100	FALSE	0.42	3.47	38.40	450	2906	3.31
25	MACK EM7-275	1998	MACK	68420	47894	100	TRUE	0.36	3.18	37.60	400	2865	3.36
25	MACK EM7-275	1998	MACK	68420	47894	100	TRUE	0.29	4.04	36.90	420	2837	3.39
26	Mack/Renault Renault MIDR 060226L/2	1994	MACK/RENAULT	25500	17850	0	FALSE	0.44	2.78	12.60	920	1208	7.94
26	Mack/Renault Renault MIDR 060226L/2	1994	MACK/RENAULT	25500	17850	0	TRUE	0.37	2.28	13.00	500	1168	8.22
26	Mack/Renault Renault MIDR 060226L/2	1994	MACK/RENAULT	25500	17850	0	TRUE	0.38	2.22	13.00	450	1158	8.29
26	Mack/Renault Renault MIDR 060226L/2	1994	MACK/RENAULT	25500	17850	0	TRUE	0.43	2.44	13.00	490	1209	7.94
27	Mitsubishi 6D34-1AT2	1999	MITSUBISHI	19360	13552	5892	FALSE	0.46	3.51	7.20	470	1427	6.73
27	Mitsubishi 6D34-1AT2	1999	MITSUBISHI	19360	13552	5892	TRUE	0.43	3.59	7.14	300	1392	6.89
27	Mitsubishi 6D34-1AT2	1999	MITSUBISHI	19360	13552	5892	TRUE	0.45	3.58	7.17	370	1424	6.74
27	Mitsubishi 6D34-1AT2	1999	MITSUBISHI	19360	13552	5892	TRUE	0.31	3.46	7.20	330	1392	6.89
27	Mitsubishi 6D34-1AT2	1999	MITSUBISHI	19360	13552	5892	TRUE	0.41	3.41	7.16	350	1392	6.89

Table 10.1-A1 Raw Data from New York Department of Energy and Conservation (*Contd.*)

Vehicle ID	Engine Type	Model Year	Make	GVW (lb)	Test Weight (lb)	Odometer (miles)	Replicate Test	THC	CO	NOX	PM mg/mi	CO2 g/mi	Fuel Economy (mpg)
28	Navistar A17SF	1996	NAVISTAR	16000	11200	277084	FALSE	0.22	1.37	9.90	340	938	10.20
28	Navistar A17SF	1996	NAVISTAR	16000	11200	277084	TRUE	0.25	1.41	9.79	270	928	10.40
28	Navistar A17SF	1996	NAVISTAR	16000	11200	277084	TRUE	0.21	1.36	9.98	300	972	9.90
28	Navistar A17SF	1996	NAVISTAR	16000	11200	277084	TRUE	0.19	1.39	9.77	260	939	10.20
28	Navistar A17SF	1996	NAVISTAR	16000	11200	277084	TRUE	0.20	1.35	9.83	240	918	10.50
29	Navistar A320	1996	NAVISTAR	33000	23100	7100	FALSE	0.15	1.22	17.30	390	1613	5.97
29	Navistar A320	1996	NAVISTAR	33000	23100	7100	TRUE	0.15	1.22	16.90	320	1594	6.04
29	Navistar A320	1996	NAVISTAR	33000	23100	7100	TRUE	0.17	1.23	17.30	290	1616	5.96
29	Navistar A320	1996	NAVISTAR	33000	23100	7100	TRUE	0.16	1.20	16.90	250	1605	6.00
30	Navistar B210F	1988	NAVISTAR	36000	25200	83500	FALSE	0.72	15.60	22.30	2790	1728	5.50
30	Navistar B210F	1988	NAVISTAR	36000	25200	83500	TRUE	0.74	14.90	21.70	2690	1720	5.52
30	Navistar B210F	1988	NAVISTAR	36000	25200	83500	TRUE	0.80	14.60	21.60	2560	1705	5.57
30	Navistar B210F	1988	NAVISTAR	36000	25200	83500	TRUE	0.73	13.60	21.50	2430	1668	5.70
31	Navistar E195 DTA466	1992	INT.HARV	32200	22540	133600	FALSE	0.94	2.43	10.70	1630	1772	5.42
31	Navistar E195 DTA466	1992	INT.HARV	32200	22540	133600	TRUE	0.87	2.24	11.20	880	1654	5.81
31	Navistar E195 DTA466	1992	INT.HARV	32200	22540	133600	TRUE	0.98	2.43	10.90	700	1720	5.58
32	Not Available	1993	INT.HARV	31020	21700	31020	FALSE	0.38	3.50	12.00	920	1545	6.21
32	Not Available	1993	INT.HARV	31020	21700	31020	TRUE	0.35	3.52	11.70	1070	1576	6.09
32	Not Available	1993	INT.HARV	31020	21700	31020	TRUE	0.36	3.53	11.80	940	1555	6.17
33	Not Available	1992	INT.HARV	25000	17500	48795	FALSE	0.69	4.74	14.20	1070	1567	6.12
33	Not Available	1992	INT.HARV	25000	17500	48795	TRUE	0.64	4.75	13.50	1020	1600	5.99
33	Not Available	1992	INT.HARV	25000	17500	48795	TRUE	0.66	4.94	13.50	990	1602	5.98
33	Not Available	1992	INT.HARV	25000	17500	48795	TRUE	0.68	5.26	13.40	990	1604	5.97
33	Not Available	1992	INT.HARV	25000	17500	48795	TRUE	0.67	5.10	13.30	890	1560	6.14
34	Renault 06-02-12	1993	MACK	32500	22750	113341	FALSE	0.21	7.51	11.00	1080	1325	7.21
34	Renault 06-02-12	1993	MACK	32500	22750	113341	TRUE	0.36	6.78	10.60	960	1333	7.17
34	Renault 06-02-12	1993	MACK	32500	22750	113341	TRUE	0.21	7.09	10.70	880	1319	7.24
34	Renault 06-02-12	1993	MACK	32500	22750	113341	TRUE	0.20	7.14	10.50	890	1276	7.48
34	Renault 06-02-12	1993	MACK	32500	22750	113341	TRUE	0.31	7.33	10.60	970	1350	7.08
35	Renault -25EM	1991	MACK	44900	31485	187960	FALSE	0.32	2.31	12.60	770	1692	5.68
35	Renault -25EM	1991	MACK	44900	31485	187960	TRUE	0.32	2.40	13.40	740	1856	5.18
35	Renault -25EM	1991	MACK	44900	31485	187960	TRUE	0.30	2.47	13.70	700	1884	5.10
35	Renault -25EM	1991	MACK	44900	31485	187960	TRUE	0.28	2.32	14.50	590	1818	5.29
35	Renault -25EM	1991	MACK	44900	31485	187960	TRUE	0.30	2.32	13.80	620	1833	5.25

Table 10.1-A2 Raw Data from Colorado School of Mines – Colorado Institute of Fuels and High-Altitude Engine Research¹

Vehicle No.	Engine Model	Model Year	Engine Make	GVW (lb)	Inertial Weight	Odometer (miles)	Run No.	Start Hot/Cold	PM HC NOX CO CO2 Fuel			
									mg	g/mi	mg	mg
2	DT466	1990	Navistar	330000	23667	142242	556	H	1.46	0.26	15.41	4.93 N/A
3	DT4660.088	1993	Navistar	25500	18049	122406	564	C	1.38	1.24	14.97	18.41
3	DT4660.088	1993	Navistar	25500	18049	122406	565	H	1.02	0.56	13.82	N/A
3	DT4660.088	1993	Navistar	25500	18049	122406	566	H	0.93	0.62	13.39	N/A
5	DT466	1987	Navistar	28000	23667	89528	593	H	2.46	2.03	9.93	14.79
5	DT466	1987	Navistar	28000	23667	89528	594	H	2.19	2.39	9.84	N/A
5	DT466	1987	Navistar	28000	23667	89528	597	H	2.29	1.79	10.02	13.93
12	6BGIXN	1993	Isuzu	220000	17120	150788	724	H	1.15	1.17	19.65	1564
12	6BGIXN	1993	Isuzu	220000	17120	150788	725	H	1.10	1.35	18.81	1474
12	6BGIXN	1993	Isuzu	220000	17120	150788	726	H	1.30	1.48	14.19	6.58
14	DT466	1995	Navistar	36220	29010	5320	747	C	1.54	0.73	20.81	12.63
14	DT466	1995	Navistar	36220	29010	5320	748	H	0.80	0.55	18.08	8.17
14	DT466	1995	Navistar	36220	29010	5320	752	H	0.76	0.57	18.15	8.69
14	DT466	1995	Navistar	36220	29010	5320	753	H	0.76	0.55	17.83	7.17
15	L10	1990	Cummins	500000	44237	72251	783	H	3.67	0.92	27.91	41.19
15	L10	1990	Cummins	500000	44237	72251	784	H	4.12	0.91	27.87	49.17
16	DT466	1989	Navistar	330000	24800	101925	792	C	2.56	1.90	39.08	30.46
16	DT466	1989	Navistar	330000	24800	101925	793	H	2.20	1.23	36.39	30.36
16	DT466	1989	Navistar	330000	24800	101925	794	H	2.14	1.19	35.20	28.50
17	NTC400	1983	Cummins	80000	50800	80876	823	H	3.55	4.54	25.27	50.44
17	NTC400	1983	Cummins	80000	50800	80876	824	H	3.47	4.31	24.78	49.65
17	NTC400	1983	Cummins	80000	50800	80876	825	H	3.49	4.08	24.07	52.03
18	V8-8-2T	1989	GMC	28000	18500	13518	848	H	1.29	0.60	13.68	5.99
18	V8-8-2T	1989	GMC	28000	18500	13518	849	H	1.09	0.45	13.26	5.79
18	V8-8-2T	1989	GMC	28000	18500	13518	850	H	1.11	0.50	13.15	63.81
19	NTC400	1981	Cummins	49560	35000	17867	863	C	4.73	7.57	21.09	25.46
19	NTC400	1981	Cummins	49560	35000	17867	869	C	4.23	9.58	20.70	26.00
19	NTC400	1981	Cummins	49560	35000	17867	870	H	3.07	6.83	19.85	26.71
19	NTC400	1981	Cummins	49560	35000	17867	871	H	3.42	6.83	19.94	29.89
20	DT466	1993	Navistar	36220	25000	37009	881	C	0.82	0.25	12.59	5.87
20	DT466	1993	Navistar	36220	25000	37009	882	H	0.72	0.28	12.36	4.95
20	DT466	1993	Navistar	36220	25000	37009	883	H	0.72	0.24	12.14	4.44

¹From a report entitled “Heavy-Duty Diesel vehicle Testing for the Northern Front Range Air Quality Study”, Colorado Institute for Fuels and High-Altitude Engine Research, February 24, 1998.

Table 10.1-A3 Test Data from West Virginia University

Test ID	Model Year	Year Tested	Test Wght (lbs)	CO g/mi	NOx g/mi	HC g/mi	PM g/mi
1093	1982	1998	46400	21.7	29.07	3.04	4.62
3089	1985	1999	42000	20.5	33.17	2.96	3.03
3090	1985	1999	42000	20.4	32.33	2.62	3.1
1360	1995	1999	42000	2.2	18.34	0.64	
1125	1998	1998	46400	4.2	19.75	1.59	0.66
1154	1998	1998	46400	4.3	20.36	1.38	

Note: Test ID 3089 is the same vehicle as Test ID 3090.

Test ID 1125 is the same vehicle as Test ID 1154.

Figure 10.2-A1 Heavy-Duty Dynamometer Driving Schedule (UDDS)

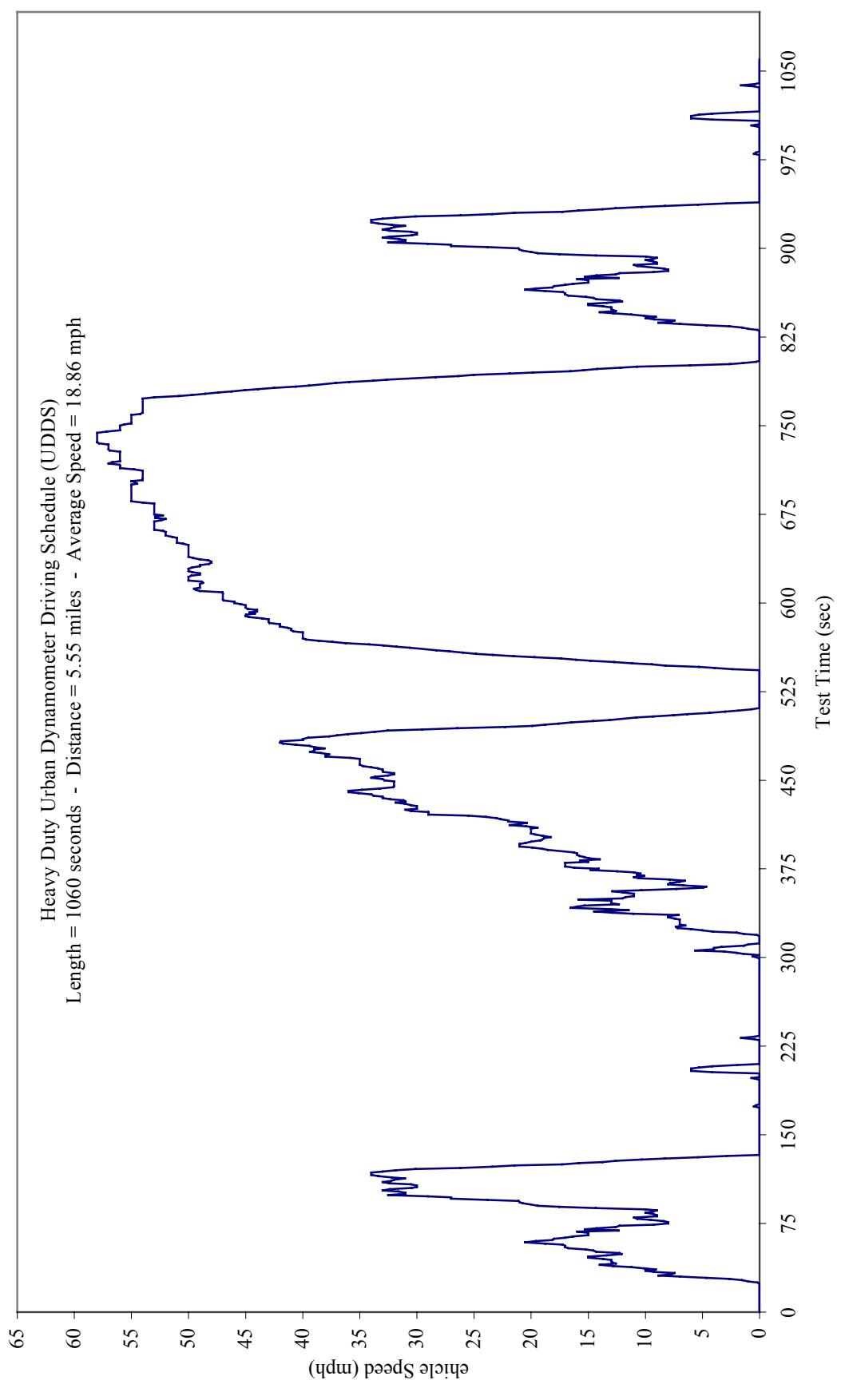


Table 10.1-A4 Raw Data for Light Heavy Diesel Trucks from U.S. EPA¹

MODEL YEAR	MAKE	MODEL NAME	GVWR (lb)	Curb Weight (lb)	Test Weight (lb)	Odometer (mi)	BAG 1			BAG 2			BAG 3				
							THC	CO	NOX	PM	CO2	THC	CO	NOX	PM	CO2	
TWGT = EMPTY + 300 LB\$																	
1988	FORD	F-250 PU	8800	6500	6500	80152	0.93	3.43	3.97	0.572	817	0.32	2.03	5.41	0.454	693	0.61
1991	DODGE	RAM 250 PU	8510	5610	67598	0.46	2.17	7.43	0.296	606	0.50	1.83	7.62	0.210	552	0.36	1.23
1993	DODGE	RAM 250 PU	8510	5800	110435	0.46	2.26	6.52	0.174	608	0.50	1.77	6.49	0.112	518	0.34	1.21
1994	FORD	F-350 PU	9200	7500	47666	0.55	3.40	7.37	0.063	595	1.31	3.95	5.28	0.076	602	0.66	2.00
1995	DODGE	RAM 2500 PU	8800	6000	114006	0.45	2.80	6.44	0.120	560	0.43	1.89	7.61	0.066	517	0.30	1.16
TWGT = FULLY LOADED (GVW)																	
1988	FORD	F-250 PU	8800	6500	8800	80152	0.60	2.93	3.93	0.832	829	0.25	1.79	5.25	0.558	716	0.54
1991	DODGE	RAM 250 PU	8510	5610	8510	67598	0.26	1.75	8.09	0.372	680	0.30	1.63	8.08	0.289	644	0.33
1993	DODGE	RAM 250 PU	8510	5800	8510	110435	0.43	1.93	6.91	0.496	674	0.53	1.57	7.32	0.362	601	0.33
1994	FORD	F-350 PU	9200	7500	9200	47666	0.72	4.01	7.42	0.079	643	1.28	4.06	6.29	0.080	601	0.66
1995	DODGE	RAM 2500 PU	8800	6000	8800	114006	0.41	2.48	7.00	0.249	653	0.38	1.58	8.50	0.073	626	0.26

¹ A test program conducted by CE-CERT for U.S. EPA to investigate the effect of payload on exhaust emission, 1999.

Table 10.1-A5 Raw Data for Light Heavy Diesel Trucks from SCAQMD - CE-CERT Report¹

Model Year	Make	Model	GVW (lbs)	Odometer (miles)	BAG1			BAG2			BAG3								
					THC	NMHC	CO	NOx	Parts.	THC	NMHC	CO	NOx	Parts.	THC	NMHC	CO	NOx	Parts.
1982	GMC	Sierra 3500 PU	10000	66355	0.56	0.57	1.76	4.61	0.259	0.27	0.28	1.37	4.09	0.112	0.29	0.29	1.50	3.36	0.186
1984	Ford	F250 PU	8600	84386	0.35	0.36	1.64	4.13	0.640	0.48	0.51	1.79	4.42	0.502	0.37	0.37	1.32	3.80	0.577
1985	Ford	F350 PU	8600	87930	0.33	0.33	1.76	3.83	0.460	0.16	0.18	0.88	4.63	0.214	0.29	0.29	1.39	3.53	0.298
1985	GMC	1500 PU	N/A	32321	1.46	1.45	2.70	2.27	0.896	0.82	0.84	1.98	2.83	0.257	0.63	0.63	1.57	2.24	0.343
1986	Ford	F250 PU	8800	57484	0.69	0.69	2.14	2.77	1.160	0.33	0.35	1.66	3.58	0.541	0.65	0.64	1.95	2.63	0.903
1987	Ford	F250 PU	8800	80342	0.57	0.58	1.67	4.28	0.918	0.50	0.52	1.34	4.34	0.518	0.49	0.49	1.47	3.90	0.836
1987	Ford	F250 PU	8800	91564	0.79	0.79	2.55	2.86	0.228	0.93	0.94	2.98	2.87	0.218	0.59	0.59	1.84	2.40	0.212
1989	Ford	F350 Stakebed	11000	58483	0.26	0.28	1.05	4.29	0.510	0.21	0.26	1.29	4.82	0.122	0.23	0.23	1.16	3.58	0.167
1992	Dodge	Ram 250 PU	8510	50405	0.52	0.53	1.61	9.29	0.209	0.58	0.58	1.40	7.68	0.145	0.35	0.35	0.95	5.29	0.165
1994	Ford	F350 PU	9200	22364	0.31	0.31	1.43	5.02	0.175	0.49	0.50	1.45	3.82	0.165	0.29	0.29	0.98	3.32	0.143
1994	Dodge	Ram 2500 PU	8800	59444	0.50	0.50	1.79	6.41	0.077	0.51	0.53	1.36	7.38	0.053	0.31	0.32	0.84	5.79	0.054
1994	Dodge	Ram 2500 PU	8800	96457	0.40	0.39	1.90	6.11	0.115	0.47	0.48	1.43	7.49	0.062	0.33	0.34	0.91	5.83	0.069
1995	Dodge	Ram 3500 PU	10500	40103	0.62	0.63	2.93	6.17	0.083	0.60	0.62	1.87	7.33	0.057	0.37	0.38	1.27	5.48	0.062
1996	Dodge	Ram 2500 PU	8800	9838	0.56	0.58	1.97	6.93	0.116	0.47	0.49	1.49	9.26	0.065	0.29	0.29	0.90	6.53	0.068
1996	Dodge	Ram 3500 PU	10500	56139	0.36	0.36	2.04	5.87	0.066	0.44	0.45	1.57	7.05	0.053	0.30	0.30	0.92	5.33	0.063

¹From a report entitled "Characterizing Particulate Emissions from Medium- and Light Heavy-Duty Diesel-Fueled Vehicles", CE-CERT, SCAQMD, September 1998.

Figure 10.2-A2 EPA Federal Test Procedure (FTP)

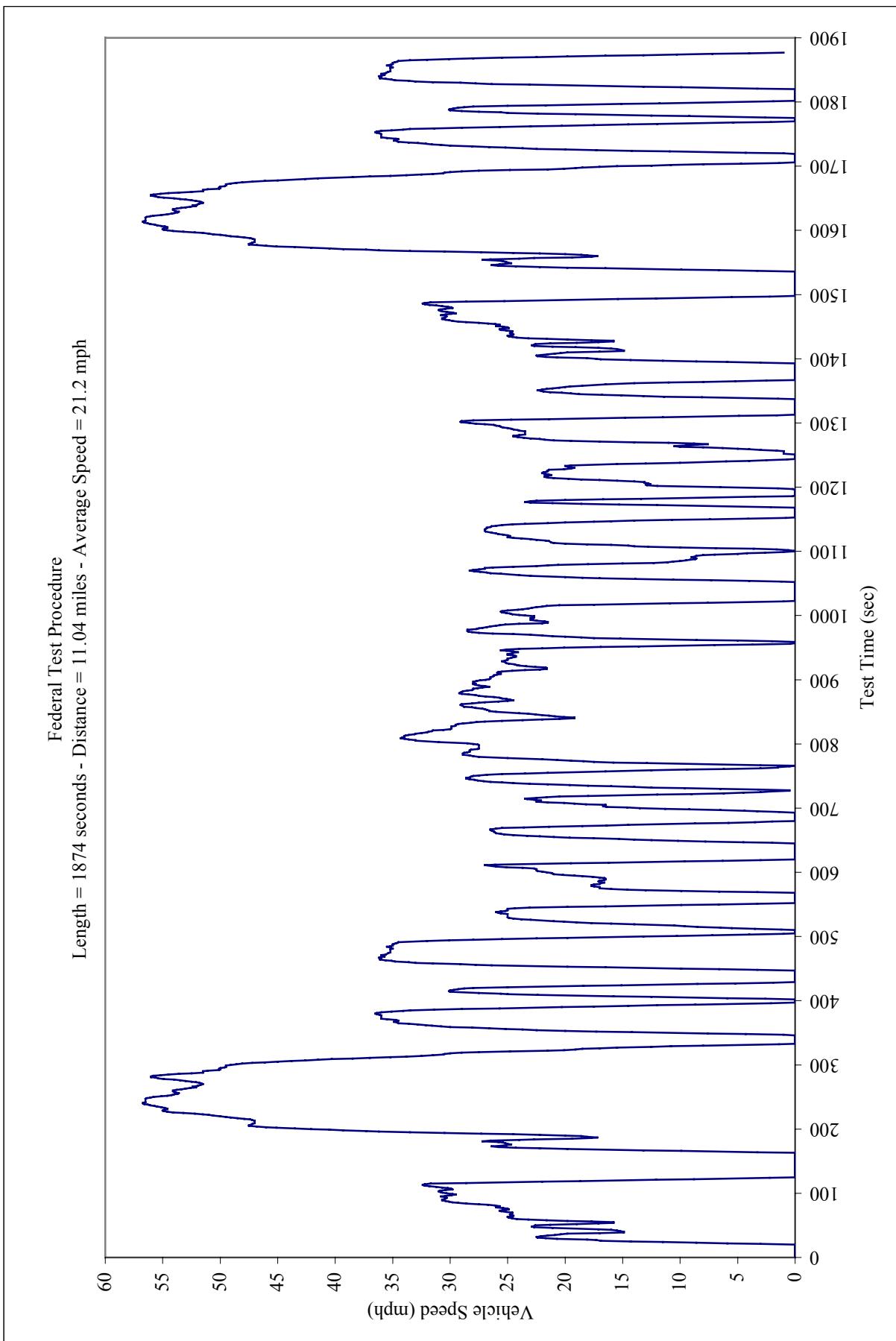


Table 10.2-A5 California and EPA On-Road Heavy-Duty Diesel Standards

FEDERAL HEAVY-DUTY TRUCK STANDARDS						CALIFORNIA HEAVY-DUTY TRUCK STANDARDS					
MODEL YEAR	HC ¹	CO	NOX	PM	HC+NOX	MODEL YEAR	HC ¹	CO	NOX	PM	HC+NOX
	g/bhp-hr						g/bhp-hr				
1974-78	---	40.0	---	---	16.0	1975-76	---	30.0	---	---	10.0
1979-83	1.5	25.0	---	---	10.0	1977-79	1.0	25.0	7.5	---	---
1984-87	1.3	15.5	10.7	---	---	1980-83	1.0	25.0	---	---	6.0
1988-90	1.3	15.5	10.7	0.60	---	1984-86	1.3	15.5	5.1	---	---
1991-93	1.3	15.5	5.0	0.25	---	1987-90	1.3	15.5	6.0	0.60	---
1994-97	1.3	15.5	5.0	0.10	---	1991-93	1.3	15.5	5.0	0.25	---
1998-02	1.3	15.5	4.0	0.10	---	1994-97	1.3	15.5	5.0	0.10	---
2003+	0.5 ²	15.5	2.0	0.10	---	1998-02	1.3	15.5	4.0	0.10	---
						2003+	0.5 ²	15.5	2.0	0.10	---

¹ Note: the HC standards shown are total hydrocarbons except for model year 2003+ which is NMHC.
² Assumes 2.5 g/bhp-hr (NOx+NMHC) with a 0.5 g/bhp-hr NMHC cap effective October 2002.

Low Emission Vehicle (LEV), Ultra-Low Emission Vehicle (ULEV) and Medium-Duty Vehicle (MDV) Emission Standards (g/bhp-hr) for Light-Heavy Diesel Trucks				
	MDV	LEV	ULEV	
NMHC+NO _x	3.900	3.000		2.500
NMHC*	0.195	0.150		0.125
CO	14.400	14.400		14.400
NO _x *	3.705	2.850		2.375
PM	0.100	0.100		0.100

* Assumption: 5% NMHC and 95% NO_x

Implementation Schedule for Light-Heavy Trucks Sales Fraction by Model Year				
Model Year	Pre 1995	MED	LEV	ULEV
1994	1.0	---	---	---
1995	0.5	0.5	---	---
1996-2001	---	1.0	---	---
2002-2003	---	---	1.0	---
2004+	---	---	---	1.0

Table 10.13-A1 Transit Bus - General Specification Data

Bus_Num	Transit Agency	Bus_Mgr.	Bus_Model	Engine_Migr	Engine Model	Engine Year	Start Mileage	GVW	Curb Weight
SL002DFDC	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	171235	39500	28250
SL003BFD	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	254255	39500	28250
SL004DFDC	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	159692	39500	28250
SL005DFDC	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	80510	39500	28250
SL006DFDC	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	160996	39500	28250
SL007BFD	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	2174	39500	28250
SL009BFD	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	204869	39500	28250
SL010BFD	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	28448	39500	28250
SL008DFDC	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1989	128395	39500	28250
MF001DFCC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1990	135376	39500	27280
MF003DFCC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1990	99753	39500	27280
MF004DFCC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1990	133214	39500	27280
MF006DFDC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1990	118895	39500	27240
MF007DFDC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1990	143465	39500	27240
MF011DFCC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1990	104759	39500	27080
MF012DFCC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1990	111569	39500	27080
MM001DGDC	Minneapolis Minnesota (MTC)	GILLIG	Phantom	DETROIT DIESEL	6V92TA	1991	1500	39600	29180
PT001DBCC	Pierce Transit (Tacoma WA)	BIA	Orion	CUMMINS ENGINE CO	L10	1991	3500	38013	26190
PT002DBCC	Pierce Transit (Tacoma WA)	BIA	Orion	CUMMINS ENGINE CO	L10	1991	3500	38013	26190
PT003DBCC	Pierce Transit (Tacoma WA)	BIA	Orion	CUMMINS ENGINE CO	L10	1991	3500	38013	26190
PT004DBCC	Pierce Transit (Tacoma WA)	BIA	Orion	CUMMINS ENGINE CO	L10	1991	3500	38013	26190
PT005DBCC	Pierce Transit (Tacoma WA)	BIA	Orion	CUMMINS ENGINE CO	L10	1991	3500	38013	26190
MF011TFC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1992	12815	39500	28460
MF012TFC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1992	11204	39500	28460
MF013TFC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1992	9531	39500	28460
MF014TFC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1992	13471	39500	28460
TM001DFCC	Tri-Met (Portland OR)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10 Celect 280	1992	0	39500	27690
TM002DFCC	Tri-Met (Portland OR)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10 Celect 280	1992	0	39500	27690
TM003DFCC	Tri-Met (Portland OR)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10 Celect 280	1992	0	39500	27690
TM004DFCC	Tri-Met (Portland OR)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10 Celect 280	1992	0	39500	27690
TM005DFCC	Tri-Met (Portland OR)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10 Celect 280	1992	0	39500	27690
MM006TGD	Minneapolis Minnesota (MTC)	GILLIG	Phantom	DETROIT DIESEL	6V92TA	1993	1500	39600	29400
MM007TGD	Minneapolis Minnesota (MTC)	GILLIG	Phantom	DETROIT DIESEL	6V92TA	1993	1500	39600	29400
MM010TGD	Metro Atlanta Rapid Transit Authority	NEW FLYER	Detroit Diesel	DETROIT DIESEL	6V92TA	1994	37920	26800	26800
AT011DND	Metro Atlanta Rapid Transit Authority	NEW FLYER	Detroit Diesel	DETROIT DIESEL	6V92TA	1994	37920	26800	26800
AT012DND	Metro Atlanta Rapid Transit Authority	NEW FLYER	Detroit Diesel	DETROIT DIESEL	6V92TA	1994	37920	26800	26800
AT013DND	Metro Atlanta Rapid Transit Authority	NEW FLYER	Detroit Diesel	DETROIT DIESEL	6V92TA	1994	37920	26800	26800

Table 10.13-A1 Transit Bus - General Specification Data (*contd.*)

Bus_Num	Trans_Agency	Bus_Mfgr.	Bus_Model	Engine_Mfgr	Engine_Model	Engine_Year	Start_Mileage	GVW	Curb_Weight
CI004DGCC	Southwest Ohio Regional Transit Author	GILLIG	Phantom	Cummins Engine Co.	M11	1996		39600	29020
CI005DGCC	Southwest Ohio Regional Transit Author	GILLIG	Phantom	Cummins Engine Co.	M11	1996		39600	29020
CI006DGCC	Southwest Ohio Regional Transit Author	GILLIG	Phantom	Cummins Engine Co.	M11	1996		39600	29020
CI008DGCC	Southwest Ohio Regional Transit Author	GILLIG	Phantom	Cummins Engine Co.	M11	1996		39600	29020
CI009DGCC	Southwest Ohio Regional Transit Author	GILLIG	Phantom	Cummins Engine Co.	M11	1996		39600	29020
CI010DGCC	Southwest Ohio Regional Transit Author	GILLIG	Phantom	Cummins Engine Co.	M11	1996		39600	29020
FL001DNDNC	Flint Mass Transit Authority (MTA)	NEW FLYER	Detroit Diesel	Series 50	1996		37920	27500	
FL002DNDNC	Flint Mass Transit Authority (MTA)	NEW FLYER	Detroit Diesel	Series 50	1996		37920	27500	
FL003DNDNC	Flint Mass Transit Authority (MTA)	NEW FLYER	Detroit Diesel	Series 50	1996		37920	27500	
FL004DNDNC	Flint Mass Transit Authority (MTA)	NEW FLYER	Detroit Diesel	Series 50	1996		37920	27500	
FL005DNDNC	Flint Mass Transit Authority (MTA)	NEW FLYER	Detroit Diesel	Series 50	1996		37920	27500	
FL006DNDNC	Flint Mass Transit Authority (MTA)	NEW FLYER	Detroit Diesel	Series 50	1996		37920	27500	
FL007DNDNC	Flint Mass Transit Authority (MTA)	NEW FLYER	Detroit Diesel	Series 50	1996		37920	27500	
FL008DNDNC	Flint Mass Transit Authority (MTA)	NEW FLYER	Detroit Diesel	Series 50	1996		37920	27500	

Table 10.13-A2 Transit Bus - Chassis Dynamometer Emissions

Bus Num	Engine Mfgr	Engine Model	Engine Year	Test Cycle	Fuel	Odometer	Setup Date	Num Runs	THC	CO	NOX	PM	CO2
SL002DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	178798	06/04/94	4	3.20	22.30	38.30	3.10	3226
SL002DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	04/17/96	04/22/96	3	7.60	38.10	0.98	2991	
SL003BFD	DETROIT DIESEL	6V92TA	1988	CBD	D2	37224	04/22/96	4	2.10	25.40	41.40	0.73	3353
SL004DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	19611	06/06/94	4	2.66	9.30	49.30	0.90	2977
SL004DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	245418	03/18/95	5	46.30	40.00	1.85	2945	
SL004DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	141193	04/16/96	4	7.80	46.00	1.16	3078	
SL004DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	121732	06/06/94	4	1.80	39.90	42.60	1.24	3185
SL005DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	135147	03/13/95	5	2.07	21.10	50.10	1.59	3116
SL005DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	190235	04/18/96	4	6.40	27.20	0.88	3100	
SL006DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	168387	06/07/94	6	1.60	33.30	39.80	1.53	3214
SL006DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	04/19/96	04/22/96	4	8.30	43.20	0.73	2912	
SL007BFD	DETROIT DIESEL	6V92TA	1988	CBD	D2	238065	04/25/96	4	6.30	53.10	0.53	3257	
SL009BFD	DETROIT DIESEL	6V92TA	1988	CBD	D2	221096	10/09/52	4	9.10	59.00	3048		
SL010BFD	DETROIT DIESEL	6V92TA	1988	CBD	D2	04/23/96	10/09/60	4	11.70	47.40	1.23	3162	
SL010BFD	DETROIT DIESEL	6V92TA	1988	CBD	D2	100960	04/23/96	4	14.30	49.50	1.15	3114	
SL010BFD	DETROIT DIESEL	6V92TA	1988	CBD	D2	100994	04/24/96	4	17.40	58.80	0.96	3053	
SL008DFDC	DETROIT DIESEL	6V92TA	1989	CBD	D2	136541	06/07/94	4	1.70	14.00	33.00	0.53	2561
SL008DFDC	DETROIT DIESEL	6V92TA	1989	CBD	D2	179543	03/20/95	4	2.29	7.40	49.10	0.72	2668
SL008DFDC	DETROIT DIESEL	6V92TA	1989	CBD	D2	230395	04/17/96	4	7.50	45.40	0.63	2730	
MF001DFCC	CUMMINS ENGINE CO	L10	1990	CBD	D2	02/07/94	02/08/94	4	40.90	36.00	0.36	3138	
MF003DFCC	CUMMINS ENGINE CO	L10	1990	CBD	D2	02/07/94	02/08/94	4	23.80	30.10	0.85	2853	
MF004DFCC	CUMMINS ENGINE CO	L10	1990	CBD	D2	02/08/94	01/18/94	4	27.10	28.40	0.77	2968	
MF006DFDC	DETROIT DIESEL	6V92TA	1990	CBD	D2	181385	01/18/94	4	2.10	9.90	18.40	2.83	2663
MF007DFDC	DETROIT DIESEL	6V92TA	1990	CBD	D2	206506	01/19/94	4	1.00	12.60	22.90	1.68	2397
MF011DFCC	CUMMINS ENGINE CO	L10	1990	CBD	D2	02/08/94	02/09/94	4	1.00	16.00	24.00	2.19	2734
MF012DFCC	CUMMINS ENGINE CO	L10	1990	CBD	D2	68251	02/09/94	4	1.90	11.30	20.70	2.68	3028
MM001DGDC	DETROIT DIESEL	6V92TA	1991	CBD	D2	55948	03/14/94	4	1.70	9.50	27.50	1.85	3189
PT001DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	43027	10/23/92	4	1.50	8.50	24.30	1.20	2733
PT001DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	07/03/95	6	1.50	13.10	21.20	1.26	2475	
PT002DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	164006	08/18/94	4	3.00	12.50	23.60	1.50	2698
PT003DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	07/15/95	4	1.20	9.50	29.40	1.29	2693	
PT003DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	107943	08/19/94	4	2.00	11.70	26.90	1.42	2933
PT003DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	07/17/95	4	1.90	9.20	25.80	1.53	2703	
PT004DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	155815	08/20/94	4	1.30	13.00	29.50	0.95	2696
PT004DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	07/18/95	4	12.80	29.90	0.32	2627		
PT005DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	144051	08/22/94	4	11.10	31.40	0.30	2783	
PT005DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	07/20/95	4	8.10	29.10	0.22	2568		

Table 10.13-A2 Transit Bus - Chassis Dynamometer Emissions (contd.)

Bus Num	Engine Mfgr	Engine Model	Engine Year	Test Cycle	Fuel	Odometer	Setup Date	Num Runs	THC	CO	NOX	PM	CO2
MF011TFC	CUMMINS ENGINE CO	L10	1992	CBD	D2	30721	02/17/93	3	17.40	29.40	0.27	2477	
MF011TFC	CUMMINS ENGINE CO	L10	1992	CBD	D2	63126	02/03/94	4	20.90	29.40	0.40	2751	
MF012TFC	CUMMINS ENGINE CO	L10	1992	CBD	D2	6684	02/17/93	3	19.10	31.30	0.29	2660	
MF013TFC	CUMMINS ENGINE CO	L10	1992	CBD	D2	9531	02/01/94	4	17.10	32.20	0.22	2592	
MF014TFC	CUMMINS ENGINE CO	L10	1992	CBD	D2	117207	07/25/95	5	2.80	15.10	25.80	0.25	2431
TM001DFCC	CUMMINS ENGINE CO	L10 Celct 280	1992	CBD	D2	140629	08/05/96	3	2.90	13.30	24.90	0.19	3761
TM001DFCC	CUMMINS ENGINE CO	L10 Celct 280	1992	CBD	D2	153295	08/02/95	3	2.30	14.20	25.60	0.09	3702
TM002DFCC	CUMMINS ENGINE CO	L10 Celct 280	1992	CBD	D2	198505	08/05/96	4	2.80	13.00	26.60	0.17	3648
TM002DFCC	CUMMINS ENGINE CO	L10 Celct 280	1992	CBD	D2	8735	08/02/95	3	2.70	12.60	22.20	1.95	3622
TM003DFCC	CUMMINS ENGINE CO	L10 Celct 280	1992	CBD	D2	54461	07/18/96	3	1.89	9.30	27.90	1.48	2403
TM003DFCC	CUMMINS ENGINE CO	L10 Celct 280	1992	CBD	D2	75581	08/03/95	5	3.20	13.00	20.00	2.29	2566
TM004DFCC	CUMMINS ENGINE CO	L10 Celct 280	1992	CBD	D2	125569	08/06/96	3	2.63	11.50	26.30	1.83	2606
TM004DFCC	CUMMINS ENGINE CO	L10 Celct 280	1992	CBD	D2	158095	08/03/95	4	2.60	12.00	21.90	1.91	2610
TM005DFCC	CUMMINS ENGINE CO	L10 Celct 280	1992	CBD	D2	210051	08/06/96	4	2.12	6.10	27.20	1.44	2645
DETROIT DIESEL	DETROIT DIESEL	6V92TA	1993	CBD	D2	10986	03/17/94	4	2.30	9.20	23.80	1.68	2579
MM006TGD	DETROIT DIESEL	6V92TA	1993	CBD	D2	6748	03/17/94	5	1.89	11.20	29.30	1.32	2510
MM010TGD	DETROIT DIESEL	6V92TA	1993	CBD	D2	128600	03/03/97	6	2.50	7.30	19.50	2.05	2562
AT011DNDC	Detroit Diesel	Series 50	1994	CBD	D2	132500	03/01/97	5	5.20	26.60	0.42	2389	
AT012DNDC	Detroit Diesel	Series 50	1994	CBD	D2	143800	03/04/97	6	2.17	6.40	33.30	0.42	2646
AT013DNDC	Detroit Diesel	Series 50	1994	CBD	D2	620900	11/07/97	6	1.29	4.00	25.10	1.67	2515
CH004DGCC	Cummins Engine Co.	M11	1996	CBD	D2	603300	11/08/97	4	4.50	46.90	1.48	2343	
CH005DGCC	Cummins Engine Co.	M11	1996	CBD	D2	53500	11/11/97	4	1.98	4.00	41.00	2.51	2299
CH007DGCC	Cummins Engine Co.	M11	1996	CBD	D2	58300	11/13/97	4	4.20	48.90	2.21	2443	
CH008DGCC	Cummins Engine Co.	M11	1996	CBD	D2	311900	11/14/97	5	2.06	43.50	2.51	2534	
CH010DGCC	Cummins Engine Co.	M11	1996	CBD	D2	607700	11/14/97	5	4.60	50.50	1.42	2412	
FL001DNDC	Detroit Diesel	Series 50	1996	CBD	D2	43100	05/23/97	4	5.60	27.00	0.34	2374	
FL002DNDC	Detroit Diesel	Series 50	1996	CBD	D2	36700	05/24/97	4	4.90	27.80	0.96	2445	
FL003DNDC	Detroit Diesel	Series 50	1996	CBD	D2	37400	05/26/97	5	5.10	28.50	1.59	2461	
FL004DNDC	Detroit Diesel	Series 50	1996	CBD	D2	37400	05/27/97	4	4.60	30.50	0.82	2439	
FL005DNDC	Detroit Diesel	Series 50	1996	CBD	D2	27500	05/28/97	6	1.83	4.40	39.60	2.30	2382
FL006DNDC	Detroit Diesel	Series 50	1996	CBD	D2	34300	05/30/97	6	4.50	48.60	2.20	2535	
FL007DNDC	Detroit Diesel	Series 50	1996	CBD	D2	40900	06/02/97	5	1.89	4.50	39.40	2.23	2510
FL008DNDC	Detroit Diesel	Series 50	1996	CBD	D2	40000	06/05/97	4	5.30	30.80	2.51	2429	

Table 10.14-A1 Urban Transit Diesel Bus Standards in g/bhp-hr

YEAR	HC	CO	NOX	PM	HC+NOx
1973-74	---	40.0	---	---	16.0
1975-76	---	30.0	---	---	10.0
1977-79	1.00	25.0	7.5	---	---
1980-83	1.00	25.0	---	---	6.0
1984-86	1.30	15.5	5.1	---	---
1987-90	1.30	15.5	6.0	0.60	---
1991-93	1.30	15.5	5.0	0.10	---
1994-95	1.30	15.5	5.0	0.07	---
1996-98	1.30	15.5	4.0	0.05	---
1999-02	1.30	15.5	4.0	0.05	---
10/2002-03	---	15.5	2.5 (NOx+NMHC) (with 0.5 g/bhp-hr NMHC cap)	0.01	---
7/2002 10/2002 2003-07 7/2003			Low sulfur diesel fuel 4.8 NOx fleet average PM Retrofit Requirements 3 bus demo of ZEBs for large fleets (>200)		
2004-06		15.5	0.5	0.01	---
2007		15.5	0.2	0.01	---
2008+			15% of new purchases are ZEBs for large fleets (>200)		

Figure 10.14-A1 NOx Emission Rates – MVEI7G v EMFAC2000

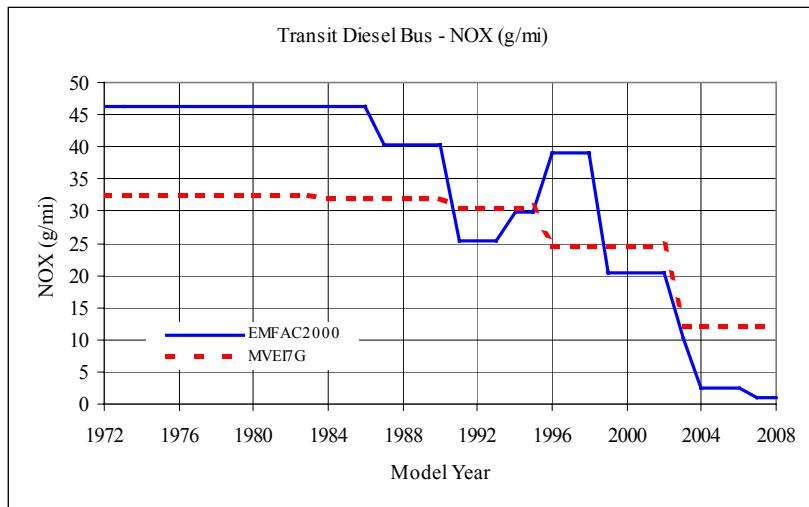


Figure 10.14-A2 PM Emission Rates – MVEI7G v EMFAC2000

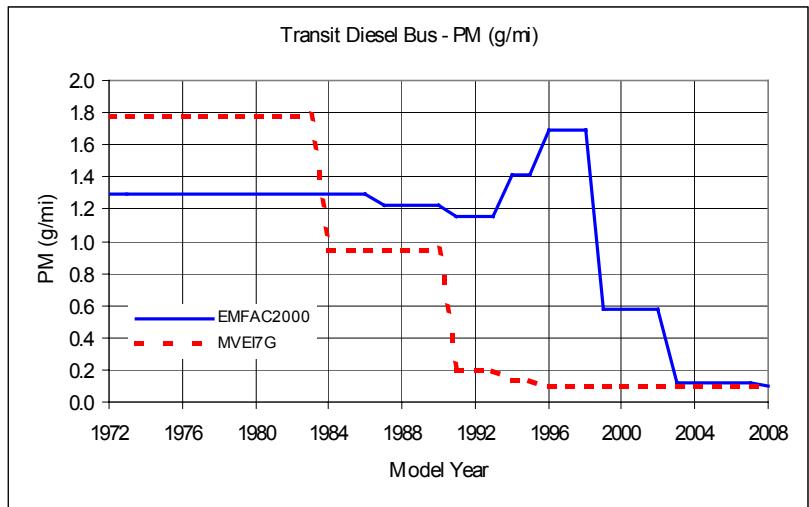


Figure 10.14-A3 HC Emission Rates – MVEI7G v EMFAC2000

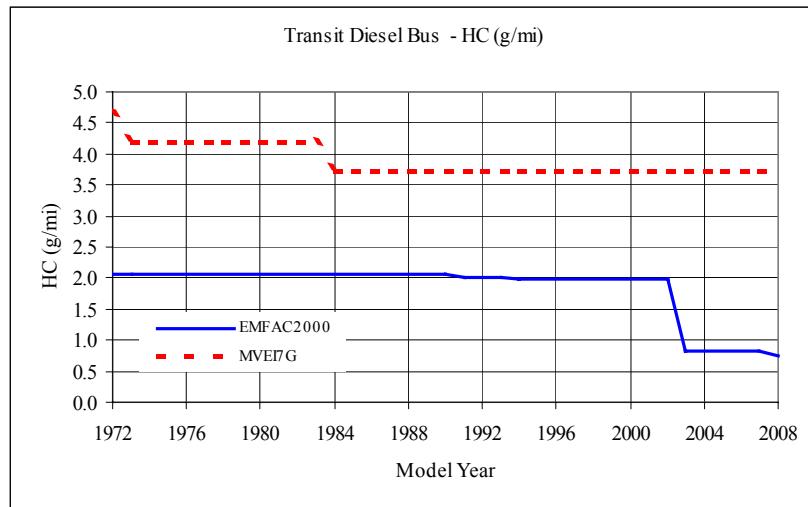


Figure 10.14-A4 CO Emission Rates – MVEI7G v EMFAC2000

